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Contents

Teeming millions in India : Certain vital issues
Vinod K. Anand

Parental education influencing schooling and child labour decision : Urban India in the new millennium
Diganta Mukherjee, Saswati Das

Capability based approach and India's poverty
Subrata Majumder

State level carborn dioxide emissions of India : 1980-2000
Tapas Choshal, Ranajoy Bhattacharyya

Multiplicity of equilibrium in canonical and non-canonical correlation devices : An example
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ARTHANITI

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Volume VII, Nos. (1-2), 2008

Contents

Teeming millions in India : Certain vital issues

Vinod K. Anand 1-12

Parental education influencing schooling and child labour decision : Urban India in the new millennium

Diganta Mukherjee, Saswati Das 13-25

Capability based approach and India's poverty

Subrata Majumder 26-40

State level carborn dioxide emissions of India : 1980-2000

Tapas Ghoshal, Ranajoy Bhattacharyya 41-73

Multiplicity of equilibrium in canonical and non-canonical correlation devices : An example

Indrajit Ray 74-84

Arthaniti 7 (1-2), 1-12 / 2008

Teeming millions in India: Certain vital issues

Vinod K. Anand[1]

Abstract
This Paper attempts to review the past approaches to population policy in general and assesses alternatives available to a developing country like India in particular. The study is divided into three sections. The first section deals with the background of the problem and general issues related to growing population all over the world. It discusses the historical trend of population growth, which was set in motion around the middle of seventeenth century that ultimately took a dangerous turn after the Second World War. The second section highlights the available policy options adopted by nations afflicted with higher population growth at different points of time. In the third section, an endeavour is made to present Indian scenario by analyzing the policies and programmes adopted by the government since the time of independence, their impact and possible alternatives for the future.

Section I

The Background

The population of the world has witnessed an unprecedented growth during the past six decades. It was 2.5 billion in 1950, 4 billion in 1975, and it has shot up to about 6 billion today, and is expected to cross 8 billion and 9 billion mark by 2025 and 2050 respectively. In fact, annual world population growth fell from 1.8 per cent in 1950 to 1.2 percent in 2000 and as per the forecast by the United Nations it will decline to 0.3 per cent by 2050. But in absolute terms, the world population is showing an upward trend. There are a few other interesting trends:

- The proportion of the world population under 15 fell from 34 per cent 1950 to 30 per cent in 2000, and it is expected to reach a level of 20 per cent by 2050;
- Average life expectancy jumped from 47 in 1950 to 65 in 2000, and is expected to reach a level of 74 by 2050;
- The proportion of people over 65 rose from 5 per cent in 1950 to 7 per cent in 2000, and is expected to reach a level of 16 per cent;
- In advanced countries life expectancy, which was 77 in 2001 is expected to reach 83 by 2050, whereas in developing countries it was 64 in 2000, and it is expected to reach the level of 74 by 2050;
- Despite interesting reduction in birth rates in several parts of the world[2], more than 90 million people are being added to globe each year. Analysis of the region-wise population statistics of the world shows that most of this growth has taken place in the developing world, particularly in Asia, Africa, and Latin America;

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[1] The author was earlier placed at the University of Allahabad as Professor and Head of Economics...

[2] The population in many rich countries is shrinking or is about to shrink because women increasingly have stopped having children. Their fertility rate in these countries has already dipped to 1.3 or less (Aiyar, 2004A).

- For the world as a whole, it is expected that population will continue to grow by another 2.5 billion people from 2005 to 2050; All of this growth will essentially be in the developing world: 1.3 billion more people in Asia, 900 million more in Africa, and the rest in Latin America;

If we analyze this increase in the world population from the point of view of the history of mankind, it is observed that more people have been added to the earth during the last six decades as compared to the historical times prior to the middle of the last century. According to a study published by the Royal Society[3], as reported in The Times of India (2003A), there are 1000 times too many people on our planet to be sustainable for very much longer. This would incur inevitable risks like mass starvation, epidemics or even extinction. For example, a wealthy nation like the United States represents approximately 5 per cent of the world population, but it consumes around 85 per cent of the world resources.

This has, therefore, aroused worldwide interest in the study of population dynamics and its impact on social, cultural, and economic development of humanity. There is a growing realization today that the consequences of unabated population growth may likely upset the balance between people and resources and the hopes and aspirations of the human beings and opportunities available to them. The development agenda pursued by various countries of the third world is feared to get upset in view of the fact that an increase in population is closely linked with economic and social change that in turn increase demand for agricultural products, employment, housing, health and other social services.

Historical records of growth of the world population from early beginning of the homo-sapiens up to the nineteenth century are merely based on speculations due to lack of supportive evidence. The available statistics are mostly fragmentary and unreliable and, therefore, much of the demographic information is born out of scholarly guesses. These fragmentary historical, anthropological and biological evidences have been pieced together for the purpose of tracing the growth of world population, which point towards the struggle between man and nature, and the success of man in adjusting, controlling, and modifying his environment. The estimates, though not very reliable, are highly useful to understand each stage of human development and the subsequent demographic consequences that have taken place.

It is believed that up to the beginning of Christian era world population remained below 250 million with the birth rates and death rates locked in a seemingly permanent equilibrium. It doubled to 500 million by 1650 and crossed the billion marks only around the middle of the nineteenth century. To add another billion to world's total population took slightly more than a century and since then nearly one billion people are being added to the global population after every 12 years. This trend of unprecedented rise in world population from around the seventeenth century onwards would end up due to the declining trend in fertility rates sometimes in the twenty-second century, but not without leaving behind its dangerous and unknown consequences for the future of human survival on the earth.

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[3] The Royal Society study *'used a statistical device called 'confidence limits' to measure what the sustainable norm should ideally be for species populations while simultaneously factoring in other variables such as carbon dioxide production, energy use, biomass consumption and geographical range.'*

Large size and rapid growth of population have far reaching serious and severe consequences on health and wealth of nations in general and developing countries in particular. The question of size and growth of human population had attracted attention of even the earliest thinkers of Greek, Roman, Confucian and Indian origins that had given different points of views on the subject. A large and rapidly growing population has sometimes been considered desirable as a source of strength and wealth of the State and as an essentially useful factor underlying technological development. Adversely, it has been viewed as a contributory factor to poverty, wars, floods, famines, epidemics, and other natural calamities. It goes to the credit of Thomas Robert Malthus (1766-1834) who, nearly 200 years ago, very strongly advocated about the adverse effect of population growth on human welfare, and argued that the tendency of population to grow faster in relation to its means of subsistence had led to human misery and placed several obstacles in the path of human progress. Studies like Ehrlich (1968) and Meadows (1972) have made the modern Malthusians to conclude that the high rate of population growth retards economic development and inevitably leads to poverty and unemployment. It could endanger the survival of humanity because supplies of life-supporting resources such as land, water, and minerals are finite. Critics of Malthus and Neo-Malthusians believe that increase in human knowledge and technological innovations would make it possible for humankind to have better standards of living despite rising populations. This debate still continues. However, despite the sharp disagreements about the future prospects, it is generally agreed that a reduction in rapid population growth in developing countries will lead to better prospects for improved living standards of additional billions of people in the decades in future.

To curb the highly accelerated growth of population, several policies and programmes have been undertaken all over the world, particularly in developing countries during the recent decades. These policy options are similar as far as their basic goals are concerned. However, the modalities of implementation may differ from region to region and from country to country according to the existing social beliefs and economic conditions of the people.

This Paper endeavours to review past approaches to population policy in general and tries to assess alternative policy measures available to a developing country like India in particular. It is divided into three sections. The first section deals with the general issues related to growing population all over the world and discusses its historical trend set in motion around the middle of the seventeenth century, which ultimately took a dangerous turn after the Second World War. It also analyzes the available policy options adopted by the nations, afflicted with higher population growth rates at different points of time. The third section focuses on the Indian scenario and analyses the policies and programmes adopted since the time of independence, their impact and the possible alternatives for the future.

Section II

Policy Options

A population policy is considered to be a deliberate attempt by a government to affect the size, structure or geographic distribution of the population. Since all the demographic variables are influenced through fertility, mortality and migration, these three factors are of particular importance in the context of any population policy. It is, therefore, essential to discuss population policy issues in respect to these components of population change. The policy measures and programmes expected to affect these critical demographic variables may be direct, indirect or both. Whereas, mortality-influencing policies are directed to bring about a reduction in mortality rates, migration-influencing policies seek to change the flow of internal migration as well as international migration. The fertility-related policies aim at influencing fertility rates and may include both pro-natalist and anti-natalist programmes, keeping in view the socio-economic needs of a nation.

After the Second World War, the World Health Organization (WHO) resolved to eradicate mass killer diseases (like malaria and cholera) and promote the concept of positive health with the aim to reduce high mortality rates prevailing at that time in most of the countries of the world. The organization was entrusted by late sixties with the responsibility of providing advisory services to government at their request on the health aspect of fertility, sterility, and fertility regulation methods, including the organization of family planning services as part of its organized health services with special emphasis on maternal and child health components. The International Conference on Primary Health Care, 1978, organized jointly by the WHO and UNICEF, at Alma Ata resolved to emphasize the need for health education and adoption of public health measures, keeping in view the social and cultural settings and technical requirements in each area. It was also stated that the highest priority should be accorded for services to the needy and under-privileged persons such as children, women, and rural population by including birth control services in maternal and child health programmes. The conference set the basic objective of 'HEALTH FOR ALL BY 2000 A.D.' to the World community.

One of the most pressing population problems today is the internal migration from rural to urban areas. This leads to increasing pressure on urban services, particularly in metropolitan regions. Another problem is differentials in density per square kilometer and flow of people from low density to high population density areas. National governments cannot prevent flow of internal migrations from one region to another or from rural to urban area (essentially because of regional imbalances) except through some incentives and encouragement policies, as it is considered to be a constitutional privilege of the citizens. To prevent this volume and directions of internal migration, therefore, the policy options like spatial distribution of population through suitable development strategies, tax incentives and disincentives for location of industries, subsidies to industries in favoured areas, investments in public enterprises, decentralization of government services, establishment of national capital in sparsely populated areas, formation of capital regions, etc. could be incorporated in population policies by the governments. As far as international migration is concerned, regulation through legislations could be adopted to maintain desired level of entry into and exist from a country.

The two types of fertility-related population policies, pro-natalist (Ash et al, 2002[4]) and anti-natalist (Birdsall et al, 2003), are adopted by the governments of different nations with reference to the social needs and priorities of their societies. Justified on the ground of high mortality rates, pro-natalist policies have existed since ancient times. The large numbers were equated with power and prosperity. Between the two World Wars, Italy, Germany, and Japan pursued pro-natalist policies through propaganda, cash payments, repression of birth control, honouring of mother-hood, regulations for emigration drives for large native populations, etc. to realize their expansionist motives. Today, several developed countries adopt these policies, though each has different motives and different approaches. In most of the countries, three types of approaches are generally adopted to have an effective pro-natalist policy. The first approach is to accept existing values and attitudes and eliminate or diminish economic liability of having children. The second is to modify norms by glorifying values relating to reproduction, and the third is to relax taboos on illegitimacy, though most of the cultures oppose this approach.

Among the direct anti-natalist policies, provision of contraceptive services, organizing family planning educational programmes, etc. have remained to be the most popular programmes throughout the world. By the acceptance of these programmes, individual couples are expected to adopt family planning, reduce fertility at micro-level and, therefore, bring about a reduction in the birth rate. By the mid-seventies, almost all the countries of the world had adopted these methods of reducing the number and spacing of children. India was the first country to adopt such a policy in 1952 followed by China and Hong Kong in 1956. Another method that is expected to control population growth rate is the liberalization of abortion laws. These laws bring down population growth rate provided medical infrastructure and health services are easily available. In most of the developing countries, however, these services are not adequate. Another policy option of raising the age at marriage, especially for women, is adopted to cut down on their reproductive span and thus reduce fertility. This hypothesis works only when the time of delay in marriage is utilized to provide more opportunities for education and employment to women that indirectly give maturity to these females to subscribe to the idea of voluntary parenthood.

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[4] This book presents a collection and analysis of original policy documents, newly translated into English, from a key period of Chinese development, providing both a current and a retrospective analysis of China's economic reform efforts. Apart from other topics the book elaborately focuses on the impact of the pro-natalist strategies on population growth.

Apart from these direct anti-natalist policies mentioned above, there are a few indirect anti-natalist policies that are used to deal with the problem of rising population. These are: provision of incentives, disincentives, improving the status of women, population education, nutrition and health services for children, urbanizing rural communities, raising the level of social and economic development and so on. These indirect programmes are expected to influence people in a way that they start accepting direct anti-natalist policies, and the rate of population starts showing a downward trend.

Section-III

The Indian Experience: Problems And Prospects

The population scenario in India is both depressing and interesting. It is depressing because despite its numerous programmes to contain population over the years, it is today the second most populous country in the world and with time the situation has gone from bad to worse. According to the 2001 Population census, the population of India stood at 1027 million comprising of about 531 million males and about 496 million females. Presently it has touched the 1.3 billion mark. Thus, India has become the second country in the world after China to cross the one billion mark. It is also predicted that by 2035, India will have a staggering population of 1.46 billion far outstripping China. Clearly all its 'holistic' family planning policies, or reproductive and child health policies, have failed. It thus does not have the resources to provide so many people a decent quality of life. Even, Arthur Lewis's idea of transferring the surplus rural population to industrial centers has not worked. It neither has the capital nor a low capital-output ratio to generate a high rate of industrial growth. The 'social overhead capital' approach to industrial development has not delivered much. There is a huge unskilled and malnourished workforce, not something that can conceivably pass off as human capital or demographic dividend. The proposition of economists like Simon Kuznets, Mahboob-ul-Haq and Amartya Sen that labour can be transformed into human capital through social sector investment has utterly failed in the context of India. The population scenario is interesting because of certain anomalies that characterize both the growth and scatter of population of the country. Some of these are listed below:

- Despite the fact that the average annual growth rate of population has declined from 2.3 per cent during 1971-81 to 2.1 per cent during 1981-91, and has declined further to 1.93 during 1991-2001, the size of population has continued to increase from 361 million in 1951 to 1027 million in 2001.As said earlier, this increase will stay to be unabated. As a consequence, India's second phase of transition with duration of 40 to 50 years will get lost by 2020. According to Lee (2003), if income per person of working age is unaffected, the decline in the number of dependents per worker would by itself raise the per capita income by about 22 per cent, adding 0.5 per cent per year to the per capita income over the given transition span. But again, rising unemployment and falling capital-output ratio, if not properly and orderly taken care of, demographic dividend would have the tendency to shift towards demographic deficit.

- The inter-state disparities in demographic parameters are highly marked. For example, according to the 2001 Population Census, out of total number of 29 States and 5 Directly Administered Union Territories, the SIX most populous States of Bihar, Madhya Pradesh, Uttar Pradsesh, Maharashtra, Andhra Pradesh and West Bengal, known as the Group of Six States (GOSS) in demographic terminology, contribute a little more than 60 per cent to India's population, while the remaining States and Union Territories, known as the Rest of India (ROI), contribute only 40 per cent. There is another important facet of this disparity in demographic imbalance. This is linked with over population and poverty, and it very well exemplifies the hypothesis that, except for a few exceptions, there exists a positive correlation between over population and poverty. A set of SEVEN States, Bihar, Jharkhand, Madhya Pradseh, Chattisgarh, Rajasthan, Uttar Pradesh and Uttrakhand, are both over populated and poverty stricken, and contribute around 43 per cent to the total population of the country.
- With a declining average annual exponential population growth rate, briefly called the Population Growth Rate (PGR), of 1.93 per cent, and the Average Annual Exponential Rate of Deceleration (RED) of 1.76 per cent, the ROI seems to have entered into the final stage of demographic transition (when growth rate begins to decline), and hence it appears that the PGR would continue to fall further during the coming decades. The story of GOSS is, however, different. Its PGR was 1.90 per cent during 1951-61, but with the Average Annual Exponential Rate of Acceleration (REA) at 0.91 per cent during 1961-71, the PGR increased to only 2.08 per cent during this decade. During the later decades although the REA continued to decline, the PGR continued to rise from 2.17 per cent during 1971-81 to 2.24 per cent during 1981-91. This is indicative of the fact that the GOSS has failed to move into the final stage of demographic transition and is trapped in the very initial stage.

The population scenario in India, thus, shows that the decline of India's PGR from 2.3 per cent during 1971-81 to 2.1 per cent during 1981-91 has been essentially due to the efforts of only 40 per cent of our population residing in the ROI, and that the attitude of the people staying in the GOSS towards population control is highly disheartening and it neutralizes the positive efforts of the residents of ROI.

Despite these depressing facts, there is also a silver lining in terms of country's demographic advantage- growing population and low-age work force- which will keep India to 'chalk out the most consistent growth over a 50 year period at an average 5 per cent. Even post 2050, India will continue to clock some of the highest growth rate in the World.'(Rajghatta, 2003B). According to another Report (The Times of India, 2003C) in this context, it is maintained that as India's population has grown, so has its productivity and, today, the country is in a position to export food to other countries. It is true that many Indians are barred by circumstances of birth and socio-economic position from realizing their full potential, but for every Indian who performs below par, there is another who makes up. Millions of IT professionals are driving the world's knowledge economy, and millions of engineering and medical professionals make up a huge percentage of the world's trained scientific manpower, and millions of farmers keep some of the world's biggest granaries full. In this context, the key world is 'millions'. It is on the strength of India's millions that the country can claim to be a great world power in the making.

We can, therefore, say with confidence that population is not a roadblock, it is a resource, and it is bliss in disguise. India's young, dynamic population is its biggest resource. Its surplus labour is a demographic dividend (The Times of India, 2004B).

It is true that India's efforts of controlling population have miserably failed in the sense that instead of reaching a goal of two children per woman, they now average about three to four children each. The future course of population growth in India will depend largely on the reproductive behaviour of the people particularly in the group of the Six States. The size of India's base population has become so large that even a low birth rate may still lead to a phenomenal increase in numbers. Looking at the urgency of the problem much would depend on the effectiveness with which various population policy options are adopted and implemented.

The problem of continuously rising population and its fallouts was well understood by some demographers, national leaders, and social activists in the country even prior to independence in 1947. It was because of this realization that when the First Five Year Plan was launched in the year 1951 the development planners gave a special focus to this issue. An official policy was, thus, framed and adopted to reduce population growth by promoting various family planning programmes. As a consequence, a population policy committee was wet up in 1952 and subsequently a family welfare cell was created in the Directorate General of Health Services. These activities were expanded and intensified in each successive five-year plan. From a 'clinical approach' to a 'community extension approach' and then to an 'integrated development approach' coupled with incentives and disincentives, the Government went on experimenting with multi-pronged family planning approaches[5]. From 1990 onwards the country also tried to introduce a series of incentives and disincentives to promote a small family norm. Some of these related to community mobilization and participation for family welfare issues for small farmers instead of target oriented family welfare programmes with the main objective of reducing fertility rate, a shift from provider-driven approach to a demand-driven approach in respect of various inputs and services, increased involvement of the NGOs and private medical practitioners, and also increased male participation.

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[5] To emphasize the voluntary nature of family planning programmes, particularly after the Excesses

Thus, all the available methods were offered to the people to enable them to make their own choice for the control of their fertility behavior. However, the progress achieved has really been slow so far essentially because of the limited scope of the country's policy and weak implementing machinery at the disposal of the government. In fact, the birth control methods and programmes of the government have been taken by most of the people and majority of politician as an intrusion in the sensitive and private matters of individuals. In addition, some religious and conservative groups also strongly oppose family planning methods. There is a general lack of the required awareness amongst the majority of people about the positive side of population control, essentially at the macro level.

Even the political leaders, termed as political entrepreneurs in the terminology of the New Political Economy, suffering from an extremely myopic vision of national interest, lack political will to effectively launch population control programmes. Apart from competing with each other to maximize their electoral support, as argued by Chadha (1997), these political entrepreneurs are also involved, irrespective of their political affiliation and party loyalties, in an unending and cut-throat inter-state rivalry in respect of the quantum of state representation in the two Houses of the Parliament. Each State wishes to maximize its representation, which according to the given Election laws, is directly proportional to population. Larger is the population of a given State, larger becomes the quantum of representation. It is for this reason that the most populous States of India (Bihar + Jhrakhand, Madhya Pradesh + Chattisgarh, Rajasthan, Uttar Pradesh + Uttrakhand, Maharashtra, Andhra Pradesh, and West Bengal) have the largest representation in the two Houses of Parliament. Taken together, these States account for more than 50 per cent of their representation in the two Houses of the Parliament in the country, and, thus, wield effective voting power there. None of these States would, therefore, ever permit their representation to be cut down at any cost, and the safest way is to adopt a lukewarm and superficial attitude towards any policy of population control. The inter-state rivalry of this nature, thus, partly explains the ineffectiveness of the population control policy in the country. This argument is also supported by the fact that the budgetary allocation for direct population control programmes in the Central and State budgets have been negligible over the years, and the family welfare programmes are substantially under funded.

Committee during emergency, the Government at the Centre replaced the name 'family planning' by 'family welfare' in 1977.

The country is, thus, placed in serious dilemma of controlling population without having the required political will, and that too in a set-up which is so wide and diverse, and where all the efforts undertaken so far to directly restrict family size have shown poor results. The lesson to be learnt from this experience is to have a policy package, which, apart from emphasizing direct methods, strongly favours a number of indirect ways, which have been seen to be effective in other countries. Before we look at these methods, let us point to another difficulty, which is perhaps specific to India. This relates to differential fertility rates. While the highly educated people coming from the lower middle, upper middle and richer strata of the population, who constitute about one-third of the country's population, have invariably shown low and regulated fertility rates and adhered to small family norms, the remaining two-third people belonging to the lower income strata have demonstrated exceptionally higher fertility rates. It is in this poverty-stricken section of the society where the population is growing at a very fast pace, as the vicious circle of poverty brings more children and too many children, in turn, lead to more poverty. This scenario augurs ill for the future, as the difficult task of eradicating poverty and bringing about sustainable development in the country would be made even more difficult in time to come.

No one would, therefore, refute the idea that all the efforts to slow the pace of population expansion (both direct and indirect) and removal of poverty are of crucial importance for the brighter future of the people. An integrated programme of development, poverty removal, and population control would go a long way in achieving this objective.

Some of the recent studies conducted in developing countries including India (Bongaarts, 1994), suggests that one in six married women in these nations, excluding China, has an unmet need for contraception and approximately one in four births in unwanted. The main causes for this are illustrated as lack of sufficient knowledge of contraceptive methods, poor sources of their supply, their adverse side effects, inconvenience in their use, disapproval by husbands, family members and others, high cost of contraceptive devices, and limited access and low quality of overall family welfare services. Improvements in the quantity and quality of family planning programmes by adopting a multi-faceted strategy for addressing these problems can bring about a substantial reduction in fertility rates. Undesirable pregnancies can be checked through programmes if women are educated and given greater control over their sexual and reproductive lives. Improvement in the status of women by assigning them equal economic, social, legal and property rights and educating the people on gender equality issues will significantly influence reproductive behavior of couples to check phenomenal growth of the country's population.

It is really disheartening to note that even after about six decades of independence India has utterly failed to enact any effective laws with regard to population control and family planning. Small countries like Switzerland and Philippines, and even big country like China have passed such legislations to check population growth. This is a high time for the Indian government to come out with a comprehensive legislative measure to solve one of the most pressing national problems by insisting that no one from any section and stratum of society in the larger interest of the country shall have more than two children. Such a law certainly needs dedication, commitment and political courage on the part of the politicians and decision makers. People in general also will have to be educated and involved to bring about the required level of mental revolution to be ready to accept the law of the land to contain population. The provisions of law, in addition, shall have to provide for adequate incentives like free education, concessions in services, old age pension, insurance coverage, etc.

The highly accelerated pace of growth in urbanization has forced big Indian cities becoming too large with concentration of the economic activities and industrial establishments. Consequently, the beneficial side effect of 'locational economics' and 'returns to scale' are exhausted and continued expansion of these concentrations is resulting in inefficient allocation of the country's valuable and scarce resources. Amidst the problems of mass poverty, underemployment and unemployment in large parts of the country, government will have to immediately initiate deliberate policies of population dispersal, say, by creating employment opportunities all over the country and try to disperse the regional concentrations of high employment, economic activities and industrial complexes. These anti-urbanization policies should specifically be directed towards the encouragement of widespread small-scale enterprises, dispersal of industrial estates, promotion of rural industries, metropolitan and city/town planning and incentives to boost industrial development in backward regions. As a result of these programmes, it is hoped, rural urban migrations would be checked to a large extent and big cities would be less burdened and the population density in the country, in general, would have some kind of an acceptable balance.

All the broad ranging approaches of population control illustrated above, if comprehensively implemented in an integrated manner, would certainly lead to large reductions in future growth of population in India. Both the demand and supply approaches of population control complement and reinforce each other. By increasing the levels of education, particularly women's education, and adult education and bringing about gender equality, demand for children could be reduced or delays in child bearing and spacing can be achieved. The consciousness created by these programmes raises demand for contraception which, in turn, could be supplemented through family planning projects by increasing availability of contraceptives, the related information and publicity services.

In terms of the above analysis it is clearly understood that the problem of population control in a country like India and the numerous solutions that have been indicated reflect socio-economic-medico focus. In order to tackle the problem effectively, it is imperative that experts in these disciplines come together and work out a feasible and practical solution. But we must remember that the problem of population control is in fact a complicated problem, and looking at what has gone by in India over the years in terms of what we have said above, the way out is not that easy. Nevertheless, we must always have a positive outlook. In this context, we should always be guided by the famous and unique 'Theory of the Second Best'[6] (Silberberg, 1990), the essence of which, in most general terms, lies in the fact that when there is a problem, there is always a solution, not necessarily the very best, but may be the second best, and even the last best. This is indeed an encouraging proposition, and this should guide the policy makers. Nothing is ever difficult, if one looks at the brighter side of the picture, and one is motivated by a strong will. Once the beginning is made, the end result shows itself in the shape of a blissful reality. Population control is not a dogmatic proposition, it is practically possible.

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Parental Education influencing Schooling and Child Labour Decision: Urban India in the New Millennium

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Abstract

This paper uses household level data from National Sample Survey Organization (NSSO) of India, the 61st (2004 – 05) round, to show that even with a significant wage incentive for schooling of urban children, the school drop out rate and child labour incidence are not small. The parents' level of education plays an important role in reducing this tendency; thus establishing the linkage between social and human capital outcomes in the family. We also look at the incidence of harmful and manual occupations among the child labour. Mother's education appears as the more important factor in curbing the manual work incidences; supporting earlier findings that women's empowerment (one important indicator of which would be female educational level) is indeed becoming instrumental in increasing parental awareness.

Key Words: School drop out, Child labour, manual work, Harmful work, Education, NSSO, India.

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1. Introduction

Childhood is a period of life to be devoted to education and training. Work done by children often jeopardizes their chances of becoming productive adults. In many places, including India, Pakistan, Bangladesh, Ghana and other countries, incidence of child labour outside the family is either rising or is significant and decreasing very slowly. This reflects a shift in attitude towards child labour itself. Initially seen mainly as a tool enabling the child to become socialized and acquire skills that will be useful to him or her in the future, it is now increasingly often seen by families as a means of supplementing their income.[1]

School dropout and child labour are major problems for the modern day society, particularly in the developing countries. Poverty forces many children to work full time for their own and their families' survival. But one can also have a situation where children live in communities that do not have adequate school facilities, so they work. In fact, many schools serving the poor are of such abysmal quality, or chances of improved upward mobility for graduates are so slim, that the expected return is not equal to the sacrifice made. The literature is replete with testimony of families that would like to educate their children, but either cannot do so, or do not feel that the inferior schools available to them merit the costs. While it is true that many children drop out of school because they have to work, it is equally true that many become so discouraged by school (because of the inferior quality of education provided) that they prefer to work (Ray, 2000 and The Probe Team, 1999). These problems mean that only 68 per cent of the world's children until age 11 complete primary education (International Labor Organization, 1996). There are several empirical studies on this. See Heady (2000), a quantitative survey for Bangladesh, focussing on the slum population of Dhaka city (Delap, 1998) and Grootaert and Patrinos (1998). Ray (2000, 2000a) found similar evidence for Ghana and Peru.

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[1] This is discussed in more detail in the excellent survey on the determinants of child labour by Brown ET. al. (2002) and the references cited therein. See also Das and Mukherjee (2007), henceforth referred to as DM.

The striking fact that its not only poverty that drives children from school to the child labour market is also illustrated by the National Sample Survey (NSS) reports showing that among the school dropouts roughly 25 percent were not in school because they were not interested. Among those employed in the child labour market, particularly for urban boys, a large proportion ($\approx$ 10%) was working not because they had to, but to acquire skill or spend time.

Bourdieu (1986) introduced social capital and cultural capital to complement economic capital, which consists of financial, physical and natural capital. He describes social capital as the actual or potential resources residing in one as a result of the investment in social relations over the years, both conscious and unintended, of the individual and its family. Cultural capital on the other hand would encompass human capital (skill formation) and education, culture as well as early socialization. Both the social and cultural capital of a child's family is important, albeit often disguised determinants of the returns to investment in education. They shape a young child's cognitive and social development, and will influence the decisions of a child's parents regarding length and quality of its education (Janssens, Van de Gaag and Gunning, 2004).

Loury (1977, 1981) was one of the pioneer authors to introduce social capital into the economics of education. He shows how differences in socioeconomic background (through social stratification, racial segregation in neighborhoods, differences in parental education and income) determine the eventual education that an individual will receive. Individuals with otherwise equal initial abilities but living in different social contexts can end up choosing entirely different educational careers. Coleman (1988) popularized the concept of social capital with its role in the creation of human capital. He emphasizes the importance of relations (in the sense of regular interaction and a cordial relationship) between the parents and the child for child outcomes. Heltberg and Johannesen (2002) found that education of the parents, especially that of the mother had a strong impact on human capital outcomes. See also Janssens, van de Gaag and Gunning (2004).

The aim of this paper is to explore this linkage between parental human capital and children outcomes (in terms of extent of schooling, tendency to drop out and decision to work as child labour). In particular, we focus on urban children as the labour market opportunities are more diverse and may require a wider set of skills from them than from children in the rural sectors. Even though poverty is likely to be a major driving force towards school dropout and child labour, we want to check if parental education and occupation structure (kind of job, manual or skilled, or nature of job contract) has any significant role to play. The analysis is done separately for the male and female children to highlight possible gender differences, for the time period 2004 – 05. We use the National Sample Survey data base for this purpose. The complexity and volume of this data makes the exercise technically difficult but given the high quality as well as the national representation, the effort is commensurate with the merit.

The rest of the paper is organized as follows. Section 2 formulates the alternative hypotheses to be tested in our context and describes the data and methodology. The results are presented in section 3.

2. The Statistical Hypotheses, Data and Methodology

Based on our above discussion, it is relevant to check whether parental level of education is important in determining the dropout or schooling decision for the child. Prior to this, we should also check whether formal education actually helps in the job market or not. This is done in **DM** who provides strong evidence for such a linkage in the adult and child labour market.

We now come to the primary question of the paper; that of the role of parental education in dropout or work decisions for the child. The relevant hypotheses are:

H_{1A}: parental education levels do not influence dropout decision for the child.

H_{1B}: parental education levels do not influence the decision to employ the child in the labour market.

Secondly, for the incidence of manual and harmful child labour, we formulate the following hypotheses:

H_{2A}: parental education levels do not influence the decision to employ the child in manual work.

H_{2B}: parental education levels do not influence the decision to employ the child in harmful work.

We formulate the relevant regression equations and the results are discussed in section 3.

Data: The present study focuses on urban children, as the incentives for education would be stronger for them in the recent years when the workforce is being progressively introduced to new products, skills and opportunities. As mentioned earlier we use the household level data collected and made available by National Sample Survey Organization (NSSO) for the 61st large sample round conducted during 2004 – 05 on employment and unemployment situation in India. Some important concepts and definitions followed in this study are described below.

The sample: The seventh quinquennial survey on employment and unemployment was conducted in the 61st round of NSS during July, 2004 to June, 2005. As usual, the survey period of this round was divided into four sub-rounds, each with duration of three months. An equal number of sample villages/

blocks (fsus) were allotted for survey in each of these four sub-rounds. At the all-India level, a total number of 12788 fsus (8128 villages and 4660 urban blocks) was allocated for the survey. The ultimate stage units are households at the subsequent stage.

Activity status: NSSO used three approaches for classification of the activity statuses of the person surveyed. These are:

(i) Number of persons usually employed - usually employed in the principal status and all workers taking into account the employed according to both the principal and subsidiary statuses,

(ii) The average number of persons employed in a week based on the current weekly status and

(iii) The average number of persons-days employed per day.

Of the three approaches, the usual principal status approach is best suited as a measure of the economic activity in an economy with seasonal fluctuations in the employment. This is because, in this approach the criteria used is the pattern of activities followed by the person for a relatively long period of time (NSSO, 2001). In our present study we considered only those urban male and female children *usually employed in the principal status* and termed them as labourers.

Household size: According to NSS (NSSO, 2001) the number of normally resident members of a household is its size. It will include temporary stay-away but exclude temporary visitors and guests. In deciding the composition of a household, more emphasis is placed on 'normally living together' than on 'ordinarily taking food from a common kitchen'.

Father's/mother's education: Adult education has been categorized as below:

a) not literate 0;

b) literate but below primary 1;

c) primary and middle 2;

d) secondary 3;

e) higher secondary 4;

f) graduate and above 5.

Informal enterprises: All enterprises with type of ownership as either 'proprietary' and 'partnership' have been treated by NSS (NSSO, 2001) as informal enterprises in the present survey.

Father's occupation: Only two categories of occupation have been considered. One category represents those who work in household enterprise (self employed) or own account worker, employer or work as regular salaried/ wage employee. An own account enterprise is an undertaking run by household labour, usually without any hired worker employed on a 'fairly regular basis'.

By 'fairly regular basis' it is meant that the major part of the period of operation(s) of the enterprise during the last 365 days (NSS, 2001). Another category is if other than these specified cases.

Child education: Child education has been categorized as below,

a) not literate 0;

b) literate but below primary 1;

c) primary 2;

d) above primary 3.

Dropout: Dropout child has been defined as who ever attended but discontinued studies to supplement household income or other reasons; or dropped out for similar reasons.

Child labour incidence: In NSS data relationships between family members can only be identified using the information regarding 'relation to head'. Due to incomplete information child labour incidence for only following two cases could be considered: 1) head of the household is father with living spouse; and 2) head of the household is grand father with only one son or one daughter with his or her spouse alive. As a result only 374 (out of 495) observations having child labour incidence and 18241 (out of 22106) observations having no such incidence could be considered for boys. Similar data loss has also occurred for the girls. It is worth mentioning here that filtering through these conditions not only reduces the sample size but may bias our results also. The family composition may be related to child labour decision.

Manual Work: According to National Classification of Occupations 1968 (NSSO, 2001), manual work is a work which essentially involves physical operations. However, jobs essentially involving physical labour but also requiring a certain level of general, professional, scientific or technical education is not to be termed as manual work. On the other hand, jobs not involving much of manual labour but at the same time nor requiring much educational background either are to be treated as manual work. Thus, engineers, doctors, dentists, midwives etc. are not considered as manual workers even though their jobs involve some amount of physical labour. But peons, chowkidars, watchmen etc. are considered as manual workers even though their work may not involve much physical labour.

Harmful work: The identification of harmful work was due to the list of state prohibited occupations prepared by the New York State Department of Labour. Effort was to make a one to one matching of these listed occupations with those of 5-digit National Industrial Classifications 2004, prepared by the Central Statistical Organization of India, though in few cases some subjective decisions were unavoidable.

Other variables:

Other variables used in our analysis are average monthly per capita expenditure as proxy for per capita income and dummies for caste (general and scheduled) and religion (Hindu and Islam).

Model Specification

We now discuss the testing of hypotheses H_{1A} and H_{1B}. For the binary dependent variables drop out and child labour incidence, we use the following probit model:

$$P(Y_i = 1) = a + \beta_1 hhsize + \beta_2 MPCE + \gamma_1 GC + \gamma_2 SC + \gamma_3 Hindu + \gamma_4 Islam + \delta_1 fgedu + \delta_2 mgedu + \delta_3 focu + \varepsilon \qquad (1)$$

where,

hhsize = household size;

MPCE = average monthly per capita expenditure;

GC = indicator or dummy variable for general caste;

SC = indicator or dummy variable for schedule caste;

mgedu = mother's education;

focu = father's occupation;

a, β's, γ's and δ's are the parameters of the model and ε is the random noise term.

$Y_1 = 1$, in case of occurence of school drop out incidence; 0 otherwise.

$Y_2 = 1$ in case of occurence of child labour incidence; 0 otherwise.

This model uses observations including both child labour and child non-labour for the two rounds.

Hypotheses H_{1A} and H_{1B} now become $H'_{1A}, H'_{1B} : \delta_1 = \delta_2 = 0$ for the relevant equations.

Regarding the hyupotheses H_{2A} and H_{2B}, the manual and harmful child labour incidences are modeled as,

$$P(Y_i = 1) = a + \beta_1 hhsize + \beta_2 MPCE + \gamma_1 GC + \gamma_2 SC + \gamma_3 Hindu + \gamma_4 Islam + \delta_1 fgedu + \delta_2 mgedu + \delta_3 focu + \eta_1 chwage + \eta_2 chedu + \varepsilon \qquad (2)$$

where η's are additional parameters for two additional explanatory variables, namely, child's wage and child's education.

$Y_3 = 1$, if child occupation is manual; 0 otherwise

$Y_4 = 1$ if child occupation is harmful; 0 otherwise.

Now the observations are restricted to the observations with child labour only, in both rounds.

Hypotheses H_{2A} and H_{2B} now become $H'_{2A}, H'_{2B} : \delta_1 = \delta_2 = 0$ for the relevant equations.

3. The Results

We start our empirical analysis by noting a few descriptive statistics as salient features of the urban child labour market in table 1. An estimated 2.2 percent of the urban boys aged 5-14 worked as labourers in 2004 - 05, in different industries in urban India against wages. The estimated number for all India urban boys was about 5.6 Lac. Looking at the girl workers, the percentage of working girls is 1.21. The estimated number in the population is 2.9 lac.

Table 1: Number of Children in the Age Group of 5 to 14, All India Urban, 2004 – 05

	In the Sample		Estimated Total	
Count	Male	Female	Male	Female
Population	22601	20607	25,867,100	23,982,000
Usually employed in principal status	495	249	566489	290182
Percentage	2.19	1.21	2.19	1.21

Next we look at the education level of parents and their income (MPCE) for relevant segments of the child population in table 2. Note that average education for the parents of children in the labour market are markedly lower than for those who are not working giving casual evidence in favour of the fact that education plays a role in child labour reduction. But as the income is lower for the families with child labour also, one needs to explore the cause and effect relationship more closely.

Table 2: Average Education and MPCE of Sample Households

Category	Male		Female	
Characteristic	Child Worker (374) (2.01%)	Child not working (18241) (97.99%)	Child Worker (177) (1.04%)	Child not working (16827) (98.96%)
Average Education of Father	0.65 (0.90)	2.34 (1.65)	0.84 (1.09)	2.25 (1.63)
Average Education of Mother	0.31 (0.69)	1.68 (1.57)	0.35 (0.81)	1.63 (1.57)
MPCE	468.13 (178.75)	834.23 (904.23)	468.90 (183.68)	798.98 (1086.41)

(Standard Deviation in Parenthesis)

We have found 215 cases of manual and 63 cases of harmful child labour incidence for the boys. The corresponding figures for the girls reveal that they are less involved in harmful work. The average education levels of parents and the children are reported separately in Table 3. It is surprising to note that the average education of the parents and the child is higher in case he is in a harmful occupation. The wage incentive for manual and harmful work for the boys is evident from the child wage figures. Also, the parents' need to send the children to such hazardous occupations is also borne out from the MPCE figures. Only exception is for the boys, where the richer parents seem to prefer to send the children to harmful work.

Table 3: Educational, Economic and Occupational Background of Sample Households with Child Worker

Catergory	Average Education of Father	Average Education of Mother	Average Education of Self	MPCE	Child Wage
Male child worker					
Manual (215) (57.49%)	0.64 (0.86)	0.28 (0.66)	0.98 (0.93)	451.27 (153.68)	224.25 (135.86)
Non-Manual (159) (42.51%)	0.68 (0.98)	0.86 (0.35)	0.34 (0.72)	490.92 (206.24)	225.05 (117.42)
Total (374) (100%)	0.65 (0.91)	0.31 (0.69)	0.91 (0.94)	468.13 (178.75)	224.63 (128.32)
Harmful (63) (83.15%)	0.78 (0.91)	0.40 (0.73)	1.06 (0.93)	488.14 (150.36)	247.56 (119.82)
Harmless (311) (16.84%)	0.62 (0,91)	0.29 (0.68)	0.88 (0.94)	464.07 (183.92)	219.98 (129.67)
Total (374) (100%)	0.65 (0.91)	0.31 (0.69)	0.91 (0.94)	468.13 (178.75)	224.63 (128.32)
Female child worker					
Manual (148) (83.62%)	0.82 (1.09)	0.64 (0.48)	0.34 (0.74)	445.26 (142.34)	195.85 (81.11)
Non-Manual (29) (16.38%)	1.03 (1.40)	0.76 (0.44)	0.38 (1.08)	589.57 (296.07)	245.62 (90.98)
Total ((177) (100%)	0.86 (1.14)	0.34 (0.80)	0.96 (0.96)	468.90 (183.68)	204.00 (84.58)

Table 4 below presents the distribution of education level among working children in the urban sector. It is starkly evident that the drop out phenomenon is sharply increasing with schooling level. This is a disturbing fact, more so because there exists substantial premium for education in the labour market for both adult and child, as reported in **DM**.

Table 4: Level of Education among Child Labour (frequency, percentage)

Education level	Male	Female		
0	163	73.42	76	34.23
1	104	46.85	40	18.02
2	87	39.19	53	23.87
3	20	9.01	8	3.60
Total	374	100	177	100

In this paper we would like to explore the role of parental education in exploring and improving the child's human capital scenario in the face of a changing social pattern and economic opportunities. It is traditionally believed that father's education level plays a major role in decision making at the household level. Thus, it is expected that in case of child schooling or labour decision, father's education will be a significant explanatory variable. Also, stability of father's income should play a major role in deciding whether a child continues schooling or drops out and possibly joins the child labour market. So this is included in our set of explanatory variables. Our primary focus is on whether the mother's education level (as a proxy for her voice in household decision making) plays any role in these decisions. So, a significant coefficient of mother's education in the presence of the other variables would indicate the significance of an educated mother's role in these decisions.

Drop out and child labour incidence

Regression output presented in Tables 5 and 6 show patterns similar to that observed in Table 2 with respect to father and mother's education, both turning out to be significant with the intuitively expected sign. This establishes the hypothesis that mother's education, even in the presence of father's education as a predictor variable, has a significant contribution to the decisions in these respects. The effect of father's occupation is more interesting. Only for boys it shows a positive significant effect. Overall it seems that *focu* either do not influence these decisions much, over and above the effect of parental education levels, or it also has an ameliorating effect on drop out and child labour incidences.

As expected, MPCE and household size has a strong impact on drop out and child labour incidence. But what is encouraging is that the education variables also have influence on these, even in the presence of MPCE as an explanatory variable. Being a scheduled caste reduces the drop out and child labour incidence in a weakly significant sense in some cases. General caste is less involved in child labour. Among the Muslims, both school drop out and child labour incidence are significantly higher.

Harmful and Manual child labour incidence

For analysing both harmful and manual child labour incidence, child wage and child education are also used as explanatory variables. We have replaced the missing values (there are some non-reporting) for child wage by the industry specific average (according to the NIC industry code). In the regression analysis for manual and harmful child labour incidence some of the explanatory variables turned out to be non-significant in both the cases. Thus we have dropped these, namely SC, Hindu, FGEDU and FOCU, from the final model presented. The results are reported in Tables 7 and 8.

For the manual work case, the overall fit is generally good. Household size turns out to have a weak positive effect on manual work incidence for the girls even though it is not significant for the boys. This is possibly because girls are usually assigned more household work and this incidence will be higher for

G165647

larger families. MPCE has the expected negative relationship in the cases where it is (at least weakly) significant. Surprisingly, father's education is insignificant. On the other hand, *focu* has emerged as an ameliorating factor for manual work.

Another surprising finding is the positive sign of the *mgedu* coefficient for the girls. Child's educational level has a positive and weakly significant coefficient in the manual occupations. This positive sign may be due to a perception of better future prospect from the child's point of view. Though this work is manual, this sector may be more productive or has a larger supply of jobs. A further support to girls working more at home, and hence in non-wage activities, is in the negative relationship between *chwage* and manual work incidence for girls in both rounds.

For the harmful work case, we have not analyzed the girls' case as the incidences are too low. The goodness of fit is very poor and only household size turns out to be significant (negative).

To summarise, we show that school drop out rate (1.55%) and child labour incidence (1.7%) is not too small[2]. The parents' level of education plays an important role in reducing this tendency; thus establishing the linkage between social and human capital outcomes in the family. We also look at the incidence of harmful and manual occupations among the child labour. Father's education now appears as the more important factor in curbing these incidences. Our study emphasizes the importance of government policy making towards enhancing the quality of schooling and enforcing school attendance. Importance of adult education programme is also not small.

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[2] See discussion on child labour incidence in Section 3. The corresponding figures for Ghana (1991-92, rural and urban combined) are 28% and 0.8% and for Pakistan (1991) are 44% and 14.5% (Heady, 2000).

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Table 5: Drop out incidence

	Male		Female	
variable	Coefficient	T-ratio	Coefficient	T-ratio
HH	1.25E-02	1.1872	3.87E-02	3.9128
MPCE	-5.99E-04	-6.1227	-2.26E-04	-2.616
GC	7.71E-02	1.5753	-6.18E-02	-1.247
SC	0.14329	2.6754	8.06E-02	1.5592
HINDU	-0.10921	-1.3165	0.31534	3.0288
ISLAM	5.85E-02	0.63737	0.37796	3.369
FGEDU	-0.13993	-7.0178	-0.10879	-5.7463
FOCU	-3.55E-02	-0.77289	-4.00E-02	-0.88135
MGEDU	-0.11747	-4.9481	-0.17506	-7.5337
constant	-1.2165	-9.5121	-1.854	-13.337
No. of obs.	18615		17004	
Log-likelihood (0)	-2468.3		-2515.9	
Log-likelihood	-2197.3		-2265.0	
Likelihood ratio test	542.060		501.857	
Mcfadden Rsq	0.10980		0.99735E-01	

Table 6: Child labour incidence

	Male		Female	
variable	Coefficient	T-ratio	Coefficient	T-ratio
HH	2.22E-02	1.826	2.07E-02	1.3249
MPCE	-6.21E-04	-4.6796	-4.17E-04	-2.5038
GC	5.30E-02	0.90665	-0.17915	-2.3138
SC	1.54E-02	0.23124	-0.16581	-1.9044
HINDU	5.32E-02	0.41326	0.14857	0.88522
ISLAM	0.33222	2.4547	0.38794	2.2038
FGEDU	-0.24991	-9.3514	-0.13225	-4.1978
FOCU	0.11921	2.1375	-9.63E-02	-1.4338
MGEDU	-0.17412	-5.1987	-0.17331	-4.2546
constant	-1.593	-9.1039	-1.9154	-8.4091
No. of obs.	18615		17004	
Log-likelihood (0)	-1831.6		-984.09	
Log-likelihood	-1520.9		-868.79	
Likelihood ratio test	621.447		230.598	
Mcfadden Rsq	0.16964		0.11716	

Table 7: Manual work (only significant variables)

	Male		Female	
Variable	Coefficient	T-ratio	Coefficient	T-ratio
HH	1.79E-02	0.43196	0.18229	2.2227
MPCE	-1.18E-04	-1.7644	-2.29E-04	-1.7221
GC	-0.54825	-3.1109	-0.60164	-1.5809
SC	-0.27983	-1.4401	-0.56269	-1.6722
HINDU	-7.91E-02	-0.1889	1.1741	1.7517
ISLAM	0.28456	0.64175	1.868	2.6958
FGEDU	1.45E-02	0.1706	-0.13805	-0.90751
FOCU	-0.72778	-4.3832	-0.39184	-1.3698
MGEDU	-0.13041	-1.0796	0.3062	1.4428
CHEDU	0.17377	2.0592	6.62E-02	0.46372
CHWAGE	-1.97E-04	-0.36408	-3.60E-03	-2.3871
Constant	1.0638	2.0618	0.41895	0.46186
No. of obs.	374		177	
Log-likelihood (0)	-255.03		-78.940	
Log-likelihood	-233.95		-61.505	
Likelihood ratio test	42.1484		34.8689	
Mcfadden Rsq	0.82635E-01		0.22086	

Table 8: Harmful work (only significant variables)

	Male	
Variable	Coefficient	T-ratio
HH	-0.12607	-2.7769
HINDU	-0.1152	-0.69467
FGEDU	9.06E-02	0.94141
FOCU	-0.16852	-0.94294
MGEDU	3.83E-02	0.29692
CHEDU	4.64E-02	0.48873
CHWAGE	7.71E-04	1.3311
Constant	-0.25076	-0.64473
No. of obs.	374	
Log-likelihood (0)	-169.58	
Log-likelihood	-162.43	
Likelihood ratio test	14.2910	
Mcfadden Rsq	0.42137E-01	

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Capability Based Approach and India's Poverty[1]

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Abstract
This paper attempts to estimate the incidence of poverty for ten major Indian states using consumer expenditure survey data generated by NSS 55th Round (1999-2000). Instead of the standard money metric approach the poverty line is defined here following a newly developed method, viz., capability measure suggested by the International Poverty Centre (2006). All the standard income poverty measures are estimated in terms of this norm and are compared and contrasted with the ones obtained from the money metric norom.

1. *Introduction:*

Hundreds of millions of Indians are poor by national and international standard. Indian policymaking and policies are dominated by discussion of poverty, and measure of poverty rightly attracted a great deal of attention in this debate. If poverty is defined as the inability to attain the minimum standard of life then the basic query centers around the definition of "standard of life" itself. The minimum calorie requirement for mere physical survival would undoubtedly dominate the fundamental poverty measure. However, the question is whether one should stop there or would extend the provision of other basic amenities (like shelter, clothing, etc.) in the definition to guarantee a minimum standard of living or not. Initially the measurement was solely dealing with income poverty, i.e., the minimum required income to ensure the minimum (decent) standard of living, and later the importance of incorporation of non-income dimensions of poverty was gradually appreciated. Consequently the concept of human poverty emerged. The transition from income to human poverty was greatly influenced by the concept of "capability". It was recognized that not only the assurance of physical survival but the guarantee of minimum social dignity and status is what need to be protected. This approach eventually treats poverty as not merely a denial of human right at a personal level but an incidence of a serious social failure.

There is no disagreement over the position that poverty is a social shame and should be immediately eradicated, however, problem is faced in identifying the poor in terms of precise quantitative measures. While income poverty defines a clear cut poverty line (in terms of minimum required annual income per person) that works as a benchmark to demarcate the poor from the non-poor, the human poverty can only come up with an assessment of the proportion of deprived population in any particular region. For all practical purposes one has to come up with a comprehensive income measure that should incorporate both the personal and the regional dimensions of deprivation. A first step towards that would be the incorporation of other dimensions of food consumption in the definition of poverty line itself. In this paper an attempt is made to assess the inter-state variations in Indian poverty scenario in terms of one such comprehensive measure known as *capability measure.*

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[1] This paper is a part of my M.Phil. Dissertation submitted in Calcutta University. In this connection I am grateful to my thesis supervisor Prof. Sarmila Banerjee. This paper was presented at UGC National Level Seminar, March 2007 held in Rabindrabharati University. I am also very grateful to Dr. Swati Ghose of Rabindrabharati University for her expert comments and advice in this regard.

2. *Organization of the paper:*

This Paper concentrates on the estimation of state-level poverty for ten selected states of India using capability based approach. The steps adopted for this purpose may be described as follows:

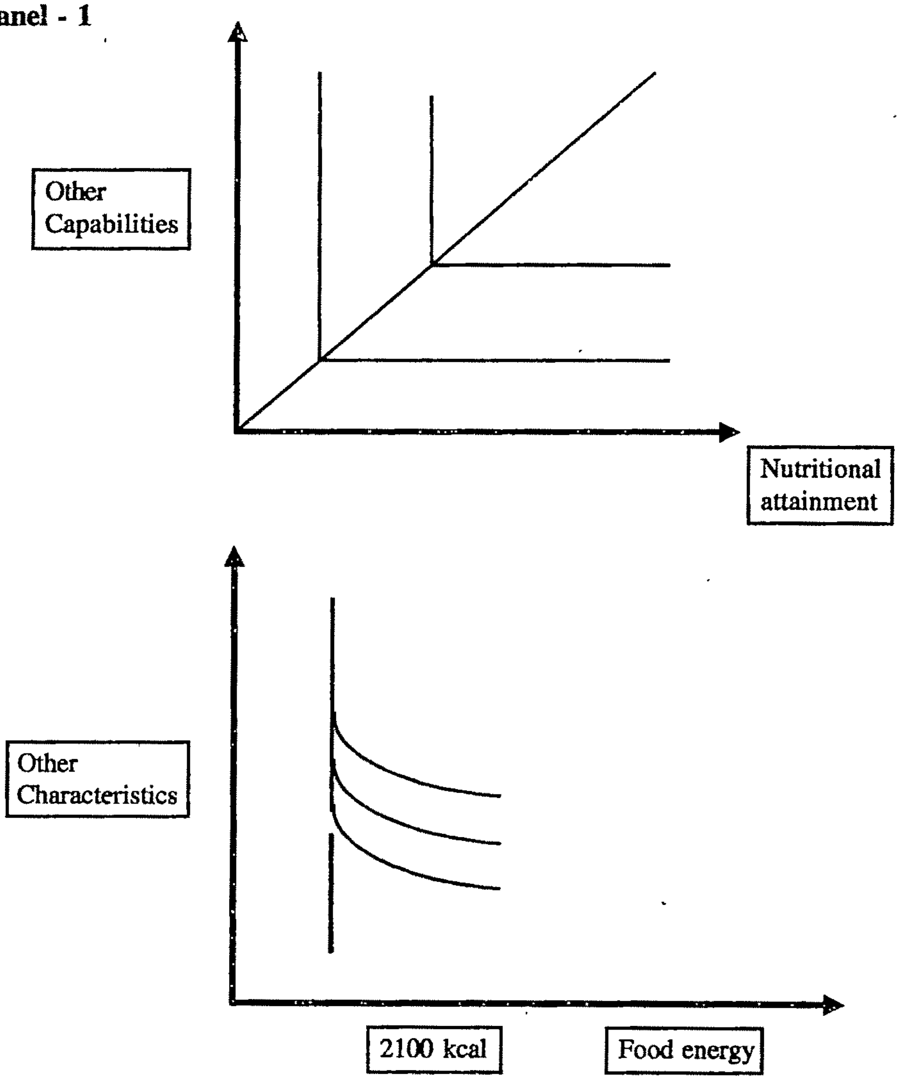
- Estimation of India's poverty line (rural and urban separately) with capability based approach using nutritional intake data of NSSO for the year 1999-2000;
- Calculation of the extent, incidence and rank of rural and urban poverty for ten major states of India using both capability based poverty line and other standard income poverty indices;
- Estimation and ranking of overall state level poverty using population weighted average of rural and urban poverty levels;
- Finally, the calculation of rank correlation between capability-based poverty indices and traditional income poverty indices for these states to understand the common-ness.

3. *Capability Approach: The Concept*

The traditional methodology of making poverty line is very simple. It considers only the cost of minimum caloric intake of a person. This means a person, whose income or per capita daily consumption expenditure is not enough to meet a certain minimum requirement of calorie intake, will be considered as a poor. This was the basic concept of income based poverty line. However, under the new concept of poverty a person is considered as poor if he is incapable to achieve the minimum necessities of life. That means only caloric insufficiency is not the ideal demarcation point of poor and non-poor, the other dimensions of incapability should allow playing their role. These associated dimensions include needs like shelter, clothing, care services, etc. If we talk about the minimum capability alone even then besides calorie intake one needs to account for the consumption of protein, fat, micronutrients, fiber etc. To define capability based poverty line other dimensions of capabilities should also taken care of. The characteristic of nutritional capabilities are easer to identify from consumer expenditure survey data provided by the NSSO. The preference function of the individual is implicitly assumed to be homothetic, which make the expenditure on nutritional capability and other capabilities equi-proportional. This assumption implies the calculation of the CBPL drastically. That means if a persons wants to achieve higher living standard through capability set he must raise his expenditure on both nutritional in-take others capabilities in a fixed proportion. Therefore in a capability space the minimum required achievement set is an L-shaped contour [Reddy S. Visaria S. And Asali M. (2006)]

Unlike calorie intake the other capability is difficult to quantify. Hence, one concentrates on more directly measurable characteristics like food energy, fats, protein, fiber, micro-nutrients and so on, on which the capability depends. This shifts our concentration from capability space to characteristic space. The characteristic space considers the two major elements one is food energy and another is other characteristic. The *first element* is measured in terms of caloric intake from cereals consumption and *other characteristic* is measured from total consumption other than food such as protein, fat, micronutrients and fiber. When the threshold level of calorie intake is guaranteed to improve the overall quality of being substitution is allowed among different components of the characteristic set. However, below this threshold level no such substitution is allowed (see panel-1).

Panel - 1



To overcome this problem the researchers have tried to focus on the food energy intake of individuals to anchor poverty line to a caloric adequacy threshold. This threshold is defined as 2100 kilocalorie (kcl) per day. A person with caloric intake larger than 2100 kcl enjoys a trade-off between the food energy and other characteristics to maintain the same contour level of adequacy set. However, if he has less than 2100 kcl then the substitution is not possible within the characteristic space. Therefore 2100 kcl consumption per day is assumed to ensure that the relevant person is enjoying not only the minimum required food energy but the other characteristic as well. That means if a persons is not able to attain 2100 kcl food energy he is considered unable to attain other non-food characteristics or incapable to enjoy the basic needs of human life.

To estimate the poverty line with this approach it is required to divide the per-capita consumption expenditure of entire population in different quintile. Now take that specific quintile where average per capita per day food energy intake is 2100 kcl. Name this quintile class as *norm quintile class*. Considerer the previous quintile class as a reference quintile class of the norm quintile class. Then calculate the average per capita per day caloric intake of that reference class. Suppose the per capita per day caloric intake of this class is x percent less than the norm class. Calculate the extra income required to lift up this reference classes from its original position to norm class. The *equi-propotional assumption* told us that the x percent extra expenditure is required for acquiring the food energy and also x percent extra non-food expenditure for accruing the nonfood characteristics to reach the norm class. That means a linear scaling up is required not only for food expenditure but for nonfood expenditure as well. Adding and aggregating the extra amount of food expenditure with original food expenditure and the non food expenditure with extra amount of nonfood expenditure of reference class we will get the countries poverty line. This amount of expenditure shows the minimum cost of achieving the minimum level of food expenditure along with the minimum level of nonfood consumption. Therefore this poverty line is called the aggregate poverty line or capability based poverty line and shows the minimum requirement of persons to acquire the basic necessity of life. The example of the construction of poverty line in Vietnam will give a concrete picture of this methodology. This approach is useful because we do not have sufficient information to estimate directly the cost of achieving nonfood capabilities considered essential for an individual's survival.

4. Poverty Line in India Using Capability Measure:

This section describes poverty line on the basis of capability based approach in Indian context considering the methodology of Vietnam VLSS. To make the Indian capability based poverty line we have used the most usable secondary NSSO (National Sample Survey Organization) data of Nutritional Intake of period July 1999 – June 2000. Here we have made some adjustment to the original Vietnam technique to build Indian capability based poverty line. First of all due to the wide disparity in cost of living of rural and urban India and due to the unavailability of suitable regional price indices we have constructed two separate poverty lines with the basis of rural and urban nutritional intake data in India and called them rural and urban capability based poverty lines. The second change that we have introduced is an equiproportional change on the basis of caloric expenditure shortfall data instead of caloric shortfall of reference class from the norm class. In our technique we have increased reference class food and nonfood expenditure on that proportion which is exactly the shortfall of caloric expenditure of reference class from the norm class. We have introduced some minor differences in assessment-technique for making it consistent with our available data structure. The third change that we have made which is the consideration of different norm calorie instead of 2100 kcl in different regions (rural and urban) due to unavailability of exact expenditure data of 2100 kcl. In Vietnam the VLSS data was used at unit level and our secondary NSSO Nutritional Intake data were utilized in a size-classed format. Now, we would like to describe the technique of derivation of rural and urban poverty line to clarify the differences and adjustments.

- *Methodology of rural poverty line setting in India using NSSO (1999-2000) data:*

NSSO reports the data on MPCE class (Rs), percentage of food expenditure of total expenditure, per capita per diem intake of calorie (kcl) and the average monthly per capita expenditure (Rs). According to the capability approach the norm intake of calorie is 2100 kcl. But due to the non availability of particular data I have considered 2054 kcl as the norm caloric intake for rural India. Therefore sixth MPCE class is considered as the norm class of rural India. In this group the expenditure share for food consumption is 64%. Now the average monthly per capita expenditure of this group is Rs. 399.90. Therefore the daily per capita expenditure is Rs. (399.90/30) = 13.33. So the daily expenditure on food of this group is Rs. (13.33 * 0.64) = 8.53. Now I have considered the fifth MPCE class which is the previous class of the norm class. Appling the same technique I have seen that the daily per capita expenditure of this class is Rs. 12.03. The daily per capita expenditure for food is Rs. (12.03 * 0.65) = 7.82. So the daily nonfood expenditure is Rs. (12.03 – 7.82) = 4.21. Therefore the amount of the expenditure of the food of this class is {(8.53 – 7.82) / 7.82} = 0.091 times less than norm group. Therefore according to the capability based approach the fifth class needs 0.091 times more expenditure for food consumption and also 0.091 times more expenditure for nonfood consumption (due to the assumption of same proportion complementarities between food and nonfood items) to reach the minimum attainable capability. To attain the minimum capability the required per capita per day expenditure is Rs. [7.80 + (7.82*0.091) + 4.21 + (4.21*0.091)] = 13.12. So in terns of 30 days it will be Rs. (13.12 * 30) = 393.60. ***So the calculated rural poverty line in India is Rs. 393.60 per capita per month.***

- *Methodology of urban poverty line setting in India using NSSO (1999-2000) data:*

NSSO reports data on MPCE class (Rs), percentage of food expenditure of total expenditure, per capita per diem intake of calorie (kcl) and the average monthly per capita expenditure (Rs). According to the capability approach the norm intake of calorie is 2100 kcl. But due to the non availability of particular data I have considered 2091 kcl is the norm caloric intake in urban India. Therefore sixth MPCE class is considered as the norm class of urban India. In this group the expenditure share for food consumption is 56%. Now the average monthly per capita expenditure of this group is Rs. 618.61. Therefore the daily per capita expenditure is Rs. (618.61/30) = 20.62. So the daily expenditure on food of this group is Rs. (20.62 * 0.56) = 11.54. Now I have considered the fifth MPCE class which is the previous class of the norm class. Appling the same technique I have seen that the daily per capita expenditure of this class is Rs. 17.91. The daily per capita expenditure for food is Rs. (17.91 * 0.58) = 10.39. So the daily nonfood expenditure is Rs. (17.91 – 10.39) = 7.52. Therefore the amount of the expenditure of the food of this class is {(11.54 – 10.39) / 10.39} = 0.111 times less than norm group. Therefore according to the capability based approach the fifth class needs 0.111 times more expenditure for food consumption and also 0.111 times more expenditure for nonfood consumption (due to the assumption of same proportion complementarities between food and nonfood items) to reach the minimum attainable capability. To attain the minimum capability the required per capita per day expenditure is Rs. [17.91 + (17.91*0.111) + 7.52 + (7.52*0.111)] = 28.25. So in terns of 30 days it will be Rs. (28.25 * 30) = 847.50. ***So the calculated urban poverty line in India is Rs. 847.50 per capita per month.***

The striking feature of this estimate is that the urban poverty line is almost double valued than the rural poverty line. The ratio between the urban and rural poverty line in case of capability based approach is 2.15. However, according to the traditional methodology, the state by state urban and rural poverty line calculated independently without consideration of the implicit urban to rural price differential, the average ratio of urban to rural poverty line is around 1.4 and varies widely across states. In the NSS 50th Round (1993/94) it is more than 1.7 in Andhra Pradesh and nearly as much in Maharastra, Madhya Pradesh and Karnataka, but less than unity in Assam (Deaton & Kozel, 2005). One plausible explanation for the disproportionate increase in urban poverty line in case of capability measure may lie in the fact that other non-food items are more costly in urban areas accounting for the higher cost of living.

5. *Poverty Estimates and NSSO-data:*

Here we have estimated Head Count Ratio (H_R), Normalized Poverty Gap (NPG), Gini Index of Poor (Gp), Sen Index of Poverty (Ps), FGT Measures of Poverty and Squared Poverty Gap (SPG) separately for rural and urban areas in each state. Then we have considered the population weighted average of rural and urban indices to measure the state poverty level. The estimation procedure is illustrated taking the state of West Bengal as an example.

Estimation of Poverty in West Bengal:

Here we have discussed how we estimate the level of poverty in West Bengal using capability based measure with Nutritional Intake Data (1999/2000) of NSSO. First we have estimated rural poverty then urban poverty in West Bengal and finally considered the population weighted average of each sectors poverty level to estimate the state level poverty.

Estimation of Rural Poverty in West Bengal:

To estimate rural poverty in West Bengal using our available data, the following steps are followed:

- ***The Estimation of Average Monthly Expenditure of Various MPCE Classes In Rural West Bengal from Nutritional Intake Data (1999/2000):***

Majumder (2006) has shown that Rs. 8.53 is required for consuming 2054 kcl. Rs. 0.00415 is the amount of required expenditure for getting 1 kcl in rural India. Considering the first MPCE classes of table 1R (from NSSO 55th Round Nutritional Intake In India) we will get the caloric consumption of the class is 1309 kcl. So the amount of expenditure of this class for caloric consumption is Rs. (0.00415 * 1309) = 5.43235. This amount of expenditure is only 71% of total average per capita per day expenditure of this class. So the total average per capita per day expenditure of this class is Rs. (5.43235/0.71) = 7.651197183. Therefore the average monthly total pre capita expenditure of this class in rural West Bengal is Rs. (7.651197183 * 30) = 229.5359115 = 229.54. Applying this methodology, table 1 estimates all classes' average monthly per capita expenditure in rural West Bengal.

- ***Estimation of Number of Persons Belonging to Different MPCE Classes In Rural West Bengal:***

Considering table 5R (from NSSO 55th Round Nutritional Intake in India) we can estimate the sample proportion of people living in different MPCE classes in rural West Bengal. If we assume the sample to be representative then sample proportions will be the best estimates of the population proportions. Then the population strength of different MPCE class can be obtained by multiplying the sample proportion with total no of rural population in West Bengal. According to the census 2001 the total number of rural population in West Bengal is 57748946. In table1 column 6 shows the number of population for each class.

Estimation of Urban Poverty In West Bengal:

To estimate urban poverty in West Bengal using our available data, the following steps are followed:

- ***The Estimation of Average Monthly Expenditure of Various MPCE Classes in Urban West Bengal From Nutritional Intake Data (1999/2000):***

From Majumder (op.cit.) we have seen that Rs. 11.54 is required for consuming 2091 kcl. Rs. 0.00552 is the amount of required expenditure for getting 1 kcl in rural India. Considering the first MPCE classes of table 1U (from NSSO 55th Round Nutritional Intake In India) we will get the caloric consumption of the class is 1352 kcl. So the amount of expenditure of this class for caloric consumption is Rs. (0.00552 * 1352) = 7.46304. This amount of expenditure is only 68% of total average per cápita per day expenditure of this class. So the total average per capita per day expenditure of this class is Rs. (7.46304/0.68) = 10.97506. Therefore the average monthly total pre capita expenditure of this class in rural West Bengal is Rs. (10.97506 * 30) = 329.2518 = 329.25. Applying this methodology, table 2 estimates all classes' average monthly per capita expenditure in urban West Bengal.

- ***Estimation of Number of Persons in Different MPCE Classes in Urban West Bengal:***

Considering the table 5U (from NSSO 55th Round Nutritional Intake in India) we can estimate the sample proportion of people live different MPCE classes in urban West Bengal. If we assume the sample to be representative then sample proportions will be the best estimates of the population proportions. Then the population strength of different MPCE class can be obtained by multiplying the sample proportion with total number of urban population in West Bengal. According to the census 2001 the total number of urban population in West Bengal is 22427251. In table 2 column 6 shows the number of population of each class.

Table 3 presents the poverty estimates for West Bengal as a whole.

Note :

- $H_R = \frac{\text{Number of people below poverty line (H)}}{\text{Total populationt (N)}}$

$TPG = \sum_{i=1}^{H}(Y_p - Y_i)$; Y_p = income poverty line

; Y_i = income of i-th poor individual.

- $NPG = \frac{APG}{Y_p} = \sum_{i=1}^{H}\frac{(Y_p - Y_i)}{HY_p}$

- $G_p = \frac{1}{2H^2\overline{Y}_\pi} = \sum_{i=1}^{H}\sum_{j=1}^{H}|Y_i - Y_j|$ $\overline{Y}_\pi$ = mean income of poor

Y_i = ith poor income

Y_j = jth poor income

- $P_S = H_R[(NPG) + (1 - NPG)G_p]$

- $FGT = P_2 = \frac{1}{N}\sum_{i=1}^{H}\left\{\frac{(Y_p - Y_i)}{Y_p}\right\}^2 = H_R[(NPG)^2 + (1 - NPG)^2(CV_p)^2]$

- To estimate the state level poverty we have considered the population pr oportion weighted average of all poverty indices (rural and urban)[2] that we have estimated. According to the census 2001 the population proportion of rural and urban West Bengal is 72% and 28%.

6. *Assessment of Poverty of Ten Major States in India by Capability Measure:*

In this section the methodology explained for the state of west Bengal has been applied in the context of nine other major Indian states where data were available separately for both rural and urban areas. Two major states like Assam and Gujarat could not be incorporated as data on urban areas were missing there. The included states are Andhra Pradesh (AP), Bihar (BIH), Karnataka (KAR), Madhya Pradesh (MP), Maharastra (MAH), Orissa (ORI), Rajastan (RAJ), Tamil Nadu (TN), Utter Pradesh (UP).

Table 4 and 5 present the estimated values and ranks of state-level poverty for all ten selected states and India as a whole. Here the state-level HPI (obtained from Shariff, 1999) is also reported to facilitate comparison. A few interesting observations are in order: (a) though in Rural WB there was a significant difference in the H_R based poverty rank and the FGT based rank, in all-WB level this difference is almost absent. Similar is the story for TN where in urban area the H_R based rank differed substantially from the FGT based rank. This apparent paradox can be resolved in terms of smoothing through aggregation procedure. (b) The ranks of the states in terms of HPI are not in general similar to those in terms of H_R or FGT. A plausible explanation may be extended as follows: weak rank correlation between H_R and FGT suggests a wide variation in the intra-poor distribution of income. Now, intra-poor distribution can vary provided there are some occupational variations. These occupational variations may take place depending on the availability of infrastructural provisions. Since, HPI is sensitive to infrastructural provisions, hence, a weak correlation between FGT and HPI may not be unexpected. The figures in Table 6 confirm our hunch.

As expected the poverty estimates obtained on the basis of Capability Measures are generally higher than those suggested by both the Planning Commission Expert Group and the NCAER studies based on standard money metric approach. The following section of this chapter will present a comparison of these alternative estimates.

7. *Comparative Analysis:*

In this section we have made a comparative analysis of our poverty measures and the traditionally calculated measures based on standard money metric approach reported in table -7 following NCAER study (1999). If we compare table -6 and table -7 then a few interesting observations come up.

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[2] Basically Headcount and FGT measures hold the decomposable property, i.e., only for these two formulae total poverty can be decomposed between rural and urban poverty, or, by implication rural and urban poverty can be combined to assess the total poverty of the state. However, to estimate state level poverty here we have implicitly assumed that this property holds in case of all poverty indices (see Bhattacharya and Coondoo).

Though the state of AP enjoys the best status in terms of conventional poverty measures the rank changes to 9 out of 10 when the poverty line is re-defined following the capability approach. The opposite happens in case of ORI and UP. These sharp but diametrically opposite responses in rank following the inclusion of other characteristics in the specification of poverty line call for an intent attention. Using the NSSO 55th Round data on rural West Bengal it has been shown by Coondoo (2004) that the inter-decile differences in the consumption of Protein and Fat are more unequal compared to that of Calorie. So, the inclusion of these other nutrients in the calculation of poverty level would affect the incidence level of poverty substantially.

Table 7 shows negative rank correlation among all the measures of poverty estimated by following two alternative definitions of poverty line. The absolute value of the correlation is the lowest for H_R and the highest for FGT. This indicates the increasing sensitivity of the measures with respect to the line change as the comprehensiveness of the measure increases.

8. *Conclusion:*

Estimation of India's poverty line in terms of capability approach showed Rs. 393.60 per capita per month in Rural India at 1999-2000 prices and the corresponding estimate for Urban India is Rs. 847.50. Thus, the urban minimum requirement is more than doubly expensive than its rural counterpart. This is not only because the urban price index is higher than the rural but the minimum requirement in urban itself is very much different from the rural one. When the line is defined in terms of the standard money-metric approach then the range of variation between rural and urban areas across Indian states lies between 0.5 to 1.7. However, the incorporation of other food consumption like fat, protein etc. caused aggravation of this difference and the incidence of poverty increased consequently.

Though now the base is higher with capability approach, the relative spread is lower, and, therefore, the Gini for poor under capability approach is consistently lower than that of the standard money metric approach. Analysis of rank correlation among all the poverty measures shows that the rank correlations between FGT and all other poverty measures for both rural and urban India are comparatively strong, the exception being H_R where it is abysmally low. This low correlation with H_R suggests the wide variation in the pattern of intra-poor income distribution across states.

Regarding the comparison of standard poverty measures and HPI a few interesting observations are in order: (a) though in Rural WB there was a significant difference in the H_R based poverty rank and the FGT based rank, in all-WB level this difference is almost absent. Similar is the story for TN where in Urban area the H_R based rank differed substantially from the FGT based rank. This apparent paradox can be resolved in terms of smoothing through aggregation procedure. (b) The ranks of the states in terms of HPI are not in general similar to those in terms of H_R or FGT. A plausible explanation may be extended as follows: weak rank correlation between H_R and FGT suggests a wide variation in the intra-poor distribution of income. Now, intra-poor distribution can vary provided there are some occupational variations. These occupational variations may take place depending on the availability of infrastructural provisions. Since, HPI is sensitive to infrastructural provisions, hence, a weak correlation between FGT and HPI may not be unexpected.

One of the striking facts revealed by the foregoing analysis is the sharp variation in state ranks with respect to the changing definition of poverty. In fact, it is well recognized in literature that poverty rates differ significantly according to the approach adopted, for countries as a whole and for regions of the world (Laderchi et al, 2006). Based on unit level National data sets, it has further been observed in India and Peru that significantly different sets of people were identified as poor according to whether the monetary, capability or participatory approach[3] to poverty was adopted. As expected the poverty estimates obtained on the basis of Capability Measures are generally higher than those suggested by both the Planning Commission Expert Group and the NCAER studies based on standard money metric approach.

The approach adopted here, through conceptually appealing, is subject to the number of data adjustment at the assessment level. In fact the reliable information of *capability* can be collected only through primary field survey. Any assessment of the basis of secondary data loses his rigor due to required approximation. Hence, the result obtain here are almost tentative. However the sensitivity of the estimates with respect to the other nutritional attainment as well as non-food capabilities is something wroth exploring.

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[3] The participatory approach aims to get people themselves to participate in decisions about what it means to be poor and the magnitude of poverty.

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Table 1: Estimation of Average Per-Capita Expenditure From Nutritional Intake Data (Rural)

MPCE Classes (Rs)	% of food expenditure of total expenditure	Per capita per diem calorie intake (kcl)	MPCE = [{0.00415) (col:-3)/(col :-2/100)] *30	Proportion of the people	Total No. of people = (57748946)* (col:-5)
(col:-1)	(col:-2)	(col:-3)	(col:-4)	(col:-5)	(col:-6)
0-225	71	1309	229.54	0.04	2274779.82 (P)
225-255	72	1535	265.43	0.04	2404977.80 (P)
255-300	72	1641	283.76	0.08	4699410.15 (P)
300-340	71	1837	322.12	0.09	5247224.29 (P)
340-380	70	1935	344.15	0.10	5905583.89 (P)
380-420	68	1994	365.08	0.10	5903127.33 (P)
420-470	68	2160	395.47	0.11	6477963.70
470-525	67	2325	432.03	0.10	5824517.23
525-615	66	2379	448.77	0.11	6561486.93
615-775	64	2648	515.12	0.11	6109478.85
775-950	60	2821	585.36	0.05	3134577.81
950-more	48	3285	852.05	0.06	3205818.21
all	-	-	-	1	57748946

Source: Calculated From NSSO Nutritional Intake In India 1999-2000 (P: Poor class).

Table 2: Estimation of Average Per-Capita Expenditure from Nutritional Intake Data (Urban)

MPCE Classes (Rs)	% of food expenditure of total expenditure	Per capita per diem calorie intake (kcl)	MPCE = [{0.00552) (col:-3)/(col :-2/100)] *30	Proportion of the people	Total No. of people = (22427251)* (col:-5)
(col:-1)	(col:-2)	(col:-3)	(col:-4)	(col:-5)	(col:-6)
0-300	68	1352	329.25	0.03	784738.46 (P)
300-350	69	1553	372.72	0.04	824613.38 (P)
350-425	66	1771	444.36	0.09	2051165.98 (P)
425-500	65	1954	497.82	0.12	2596654.91 (P)
500-575	60	1918	529.37	0.10	2245755.59 (P)
575-665	59	2103	590.27	0.10	2197905.69 (P)
665-775	57	2067	600.52	0.10	2221830.64 (P)
775-915	56	2220	656.49	0.10	2264895.56 (P)
915-1120	52	2270	722.91	0.11	2376545.34 (P)
1120-1500	49	2434	822.59	0.11	2520095.06 (P)
1500-1925	43	2604	1002.84	0.06	1291947.47
1925-more	40	3478	1439.89	0.05	1051102.94
all	-	-	-	1	22427251

Source: Calculated From NSSO Nutritional Intake in India 1999-2000 (P: Poor Class).

Table 3: Estimation of Poverty in West Bengal

Indices (col:-1)	Rural Proportion (col:-2)	Urban Proportion (col:-3)	Rural Poverty (col:-4)	Urban Poverty (col:-5)	State Poverty [(col:2)(col:4)+(col:3)(col:5)] (col:-6)
H_g	0.72	0.28	45.77	89.55	58.02
NPG	0.72	0.28	23.35	34.32	26.42
Gp	0.72	0.28	8.77	14.95	10.50
P_s	0.72	0.28	13.76	39.53	20.97
FGT	0.72	0.28	3.43	12.3	5.91
SPG	0.72	0.28	5.45	11.78	7.22

Source : Calculated From NSSO Nutritional Intake In India 1999-2000.

Table 4: Poverty of Ten Major States in India Using Capability Based Method

States	H_R (%)	NPG (%)	Gp (%)	Ps (%)	FGT (%)	SPG (%)	HPI (%)
AP	62.23	26.86	10.90	23.49	7.25	8.46	39.78
BIH	58.96	19.29	9.23	16.16	2.71	3.84	52.34
KAR	52.76	27.32	10.49	19.74	6.30	7.93	32.10
MP	51.21	19.93	8.07	14.75	2.91	4.34	43.47
MAH	56.37	23.16	9.26	19.35	5.54	5.99	29.25
ORI	52.24	18.96	7.87	13.80	2.25	3.71	49.85
RAJ	25.93	19.67	6.91	8.90	2.88	4.45	46.67
TN	67.44	30.74	12.02	26.95	8.82	10.12	29.28
UP	30.96	18.24	5.38	11.08	2.27	3.79	48.27
WB	58.02	26.42	10.50	20.97	5.91	7.22	40.48
AI	43.08	21.55	9.19	13.96	3.95	5.04	39.36

Source : Calculated From NSSO 55th Round Data.

Table 5: Rank of Ten Major States According Poverty in India Using Capability Based Methods

States	H_R	NPG	Gp	Ps	FGT	SPG	HPI
AP	9	8	9	9	9	9	4
BIH	8	3	5	5	3	3	10
KAR	5	9	7	7	8	8	3
MP	3	5	4	4	5	4	6
MAH	6	6	6	6	6	6	1
ORI	4	2	3	3	1	1	9
RAJ	1	4	2	1	4	5	7
TN	10	10	10	10	10	10	2
UP	2	1	1	2	2	2	8
WB	7	7	8	8	7	7	5
AI	-	-	-	-	-	-	-

Source : Calculated From from Table-4.

Table 6: Rank Correlation between Capability Based and Multidimensional Indies

	H_R	NPG	Gp	Ps	FGT	SPG	HPI
H_R	1	*	*	*	*	*	*
NPG	0.633	1	*	*	*	*	*
Gp	0.891	0.930	1	*	*	*	*
Ps	0.903	0.867	0.988	1	*	*	*
FGT	0.661	0.976	0.903	0.879	1	*	*
SPG	0.633	0.964	0.879	0.843	0.988	1	*
HPI	-0.406	-0.830	-0.685	-0.673	-0.830	-0.818	1

Source : Calculated From Table-5

Table 7: Rank Correlation between NCAER Poverty Measures and Capability Based Poverty Measures

Indices	H_R	NPG	G_p	P_s	FGT	SPG
Rank Correlation	-0.297	-0.357	-0.418	-0.430	-0.606	-0.418

Source : Calculated from NHDR (2001), IHDR (1990) and NSS 55th Round.

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State Level Carbon Dioxide Emissions of India: 1980-2000

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Abstract

We estimate the state level CO_2 emissions for India between 1980 and 2000 from their fuel usage pattern. It is found that coal is the most important source of CO_2 in all the states. The relationship between per capita gross state domestic product and CO_2 follows an inverted U-shape. The shape is totally dictated by the inverted U-shaped relationship between per capita gross state domestic product and coal consumption.

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1.1 Introduction

Emission of greenhouse gases is one of the major sources of pollution in the world. The most well documented harmful effect of greenhouse gases is global warming[1]. Of the five major greenhouse gases causing global warming carbon dioxide (CO_2) is the most abundant[2]. It is also the most popular among academicians and activists all over the world. Apart from the quantitative significance of its emissions and it's potential to hurt humans there are other reasons for the attention that it gets. For example the Kyoto protocol[3] and the debates involving it have made CO_2 a household topic. For researchers, there is another more important reason: availability of data. Unlike other pollutants, we have consistent yearly estimates of CO_2 for all countries of the world for amazingly long periods of time dating back to the early nineteenth century. The Carbon Dioxide Information Analysis Center (CDIAC) of the Oak Ridge National Laboratory (ORNL) provides these estimates (based on the usage of major CO_2 emitters and conversion factors that translate this usage to CO_2 emissions). The data have been extensively used by researchers to address a wide range of issues pertaining to CO_2.

The ORNL estimates are at the country level. An obvious extension, especially for geographically large countries, is to understand the regional distribution of these country level emissions. Unlike the country level data, data at the regional level are expected to be more homogeneous and hence more reliable in pin pointing the determinants of emissions. The objective of this paper is to estimate the regional (state wise) distribution of India's CO_2 emissions[4] from 1980 to 2000, years for which comparable energy data were available at the state level. After presenting the estimates we will make a simple scatter plot analysis of the data with respect to per capita income of the states and the fuel sources from which the data is estimated.

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[1] There are other harmful effects like increasing pest attacks, erratic changes in weather etc. Many of these are indirect consequences of global warming.

[2] The others are methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbon (CFC), and tropospheric ozone.

[3] This international response to climate change was launched in 1992, at the Earth Summit in Rio de Janeiro, with the signing of the U.N. Framework Convention on Climate Change. The Convention established a long-term objective of stabilizing greenhouse concentrations in the atmosphere "at a level that would prevent dangerous anthropogenic interference with the climate system." It also set a voluntary goal of reducing emissions by developed countries.

It should be mentioned here that India is the fourth largest CO_2 emitter of the world (see Table 1). It is in fact the only low-income country in the top ten. The global trend for CO_2 emissions is such that emission by the high-income countries far exceeds the middle and lower income countries (Figure 1). In fact the high-income countries account for more than 71 per cent of aggregate global CO_2 emissions while low-income countries account for only about 5 per cent. Thus, going by incomes, the level of emissions for India is much beyond expectations. However this is not true for other possible determinants of CO_2. For example India is the second most populated country in the world and fourth largest in terms of GDP (PPP). These factors have obviously played an important role in determining the quantum of emissions and overwhelmed the depressive influence due to the paucity of per capita income.

Also source-wise India is significantly different from global averages (Table 2). The major global sources of CO_2 emission are liquid fuels (mainly petroleum products). Solid fuels (mainly coal) come second in importance. However in India solid fuel is much more important than liquid fuel. For the world the solid: liquid ratio is 33:44[5]. In India it is 68:24.

The rest of this paper is arranged as follows: Section 2 describes the methods applied for estimation of CO_2 emission at the state level. Section 3 provides an overview of the data sources used in this paper. Section 4 contains the results on the state level CO_2 emission of India. Section 5 concludes the paper.

2. Methodology

Table 3 provides the known sources of CO_2 in the world. Anthropogenic sources (excluding respiration, which is considered as a 'natural' source) account for 80 per cent of aggregate emissions[6]. Of the natural sources respiration and fire are most important. Among the anthropogenic sources burning of fossil fuels is by far the most important accounting for more than 80 per cent of emissions from this source. Deforestation and Cement manufacturing[7] are the other two major sources accounting for 17 per cent and 3 per cent respectively[8]. Among fossil fuels petroleum products and coal are the most important[9].

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[4] See Hutington (1994) and Aldy (2004) for a similar exercise in the US. In addition to estimation, they have analyzed the data as well.

[5] Apart from solid and liquid fuels other sources of CO_2 emission are gas fuel, gas flaring and cement manufacturing.

[6] See Panayoutou (1999)

[7] The method of estimation for CO_2 estimation from cement manufacturing along with the extent of CO_2 emission from this source for the Indian states have been furnished in the Appendix II.

[8] See Pepper et al (1992)

In order to generate state level estimates for India in this paper we apply the methodology adopted by the ORNL. The basic methodology is as follows: first the major sources are identified. Next data are collected for these sources. Finally conversion factors are used to calculate emissions from different sources. There are however many important issues involved in every step and adjustments are necessary to the ORNL methodology to adapt it for available energy data on Indian states. We explain these in details before reporting the estimated values of emission.

2.1 Method of Estimation

Table 4 reports the sold, liquid and gaseous fuels that are used for estimating CO_2 emissions. Data regarding some of these fuels could not be obtained for the Indian states (though all of them are available for India as a whole). In particular, state level data regarding the following fuels were not available: natural gas, crude petroleum, lignite, oil shale and peat and also some other secondary fuels like refinery gas, plant condensate, feedstock, jet fuels, briquettes and gas coke. Thus the estimate is based on the following fuels: LPG, naphtha, motor gasoline, kerosene, high speed diesel oil, light diesel oil, furnace oil, low sulphur heavy stock[10], and coal.

The methods of Marland and Rotty (1984) were used to estimate the amount of CO_2 emitted to the atmosphere from fossil fuel burning. The calculation of CO_2 emissions from fossil fuels is conceptually very simple. For each type of fuel, the annual CO_2 emissions are the product of three terms: the amount of fuel consumed, the fraction of the fuel that is oxidized, and a factor for the carbon content of the fuel:

$$CO_{2i} = (P_i)\ (FO_i)\ (C_i)$$

where subscript *i* represents a particular fuel, *P* represents the amount of fuel *i* that is consumed each year, *FO* is the fraction of *P* that is oxidized, *C* is the average carbon content for fuel *i*, and CO_{2i} is the resulting CO_2 emissions for fuel *i* expressed in mass of carbon. For CO_2 emissions, fossil fuels can be divided into the usual groups of solid, liquid, and gas fuels[11]. The factors and units for calculating CO_2 emissions from fossil fuel consumption are furnished in Box-I. The emissions coefficients (C_i) are defined in such a way as to express as accurately as possible the fuel carbon content in terms of easily accessible measures of the quantity of fuel consumed. The mean carbon content of liquid fuels is most accurately estimated in terms of the mass fraction while the carbon content of solid and gas fuels is most accurately estimated in units of mass C per unit of energy content. Using energy content in the denominator compensates for the wide variability in the chemical and physical properties of coals (Marland et al. 1994a) and captures the variability of gaseous fuels as well.

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[9] In case of India around 68 per cent of CO_2 emission comes from solid fuels (mainly coal) and around 24 per cent is from petroleum products.

[10] Low Sulphur Heavy Stock (LSHS) is a residual fuel processed from indigenous crude. This fuel is in lieu of furnace oil in the same applications where furnace oil is suitable.

[11] For the Indian states data on production or consumption of natural gas are not available.

Box 1: Factors and units for calculating CO_2 emissions from fuel consumption

From primary and secondary gas fuel production or Consumption[a]

CO_{2g} = CO_2 emissions in 10^6 metric tons of carbon

P_g = annual production or consumption in thousands of 10^{12} joules

$FO_g = 0.98 \pm 1\%$

C_g = carbon content in 10^6 tons per thousand 10^{12} joules = $0.0137 \pm 2\%$

From crude oil and natural gas liquids production or consumption[b]

CO_{2l} = CO_2 emissions in 10^6 metric tons of carbon

P_l = annual production or consumption in 10^6 tons

$FO_l = 0.918 \pm 3\%$

C_l = carbon content in tons C per ton fuel = $0.85 \pm 1\%$

From primary and secondary liquid fuel production and trade in the national accounts when non-energy liquid products are specifically subtracted

CO_{2l} = CO_2 emissions in 10^6 metric tons of carbon

P_l = annual production or consumption in 10^6 tons

$FO_l = 0.985 \pm 3\%$

C_l = carbon content in tons C per ton fuel = $0.85 \pm 1\%$

From primary and secondary solid fuel production and trade

CO_{2s} = CO_2 emissions in 10^6 metric tons of carbon

P_s = annual production or consumption in 10^6 tons coal equivalent

$FO_s = 0.982 \pm 2\%$

C_s = carbon content in tons C per ton coal equivalent = $0.746 \pm 2\%$

Source: Marland and Rotty (1984)

3. Data Sources

The energy data have been compiled by Economic Intelligence Service of the Centre for Monitoring Indian Economy Private Limited (CMIE), Mumbai. CMIE provides a long time series data on consumption or production of petroleum, natural gas, electricity, coal and lignite. The state wise consumption of coal and the petroleum products like liquefied petroleum gas, naphtha, motor gasoline, kerosene, high speed diesel oil, light diesel oil, furnace oil and low sulphur heavy stock are available in the publication "Energy, May,2005". Thus our estimate is essentially based on consumption. The details of the data sources by type of fuel have been furnished in Appendix I. The income variables used in the statistical analyses represent Gross State Domestic Product (GSDP) for different states and are taken from the respective State Directorates of Economics and Statistics. The population data is taken from The Registrar General of India (annual estimated mid-year population of states). Population data have been used to generate state level per capita emission and also to carry out the statistical analysis.

4. Results

4.1 Comparing Our Results with ORNL

It has already been noted that the main aim of this paper is to provide a breakup of India's aggregate CO_2 emissions according to the contribution by states. Adding up the state emission levels we get the aggregate emission for India as a whole. This aggregate should ideally match the estimates made by ORNL. Figure 2 and Table 5 compares our estimates with that of ORNL. It is clear from Figure 2 that our estimate has an upward bias (around 12 per cent on an average) although our source-base is smaller (some of the sources considered by ORNL for the estimation of CO_2 emission for India could not be taken into account at the state level due to non-availability of the corresponding energy data for the states). An indication as to what these missing sources are was provided in section 2.1. As the source of data used by ORNL at country level is not known it is difficult to locate the specific reason behind this bias. There might be some aggregation bias caused due to difference in the source datasets. However the two lines in Figure 2 are almost parallel suggesting that the two sets of estimates are internally consistent. A shift of origin will make the two estimates almost identical.

4.2 Estimated CO_2 Emission

4.2.1 Taking States Separately

Uttar Pradesh leads the Indian states as far as mean CO_2 emissions between 1980 and 2000 is concerned. It is closely followed by Madhya Pradesh, Maharashtra and Bihar[12] (Figure 3). It can be seen from Table 6 that in tune with the general trend in India all these states have a high proportion of emissions from coal (82 %, 92 %, 74 %, and 89 % respectively). In case of Maharashtra and Uttar Pradesh two other significant sources are motor gasoline (2.2 % and 1.1%) and high-speed diesel oil (9.6 % and 8.8 %). However in case of Madhya Pradesh CO_2 emission from these sources is only around 4.8 per cent (see Table 7).

A cursory look at Figure 3 and Table 6 appears to show that, as we have already guessed, the size of population of a state is one of the indicators of the quantum of CO_2 emission. States with small population sizes like Jammu and Kashmir, Himachal Pradesh, Assam, and Goa have low emission levels. However population is definitely not the only indicator. As states like Kerala, which has higher population than Rajasthan and Delhi have significantly lower emission levels. Nor can states be clearly ranked according to their levels of economic progress. If we were to do so, undivided Madhya Pradesh and Uttar Pradesh will be clear exceptions as they have the highest level of emissions but not a high level of income[13]. Thus Figure 3 and Table 6 suggest that finding determinants of CO_2 emission would be a highly interesting exercise for the Indian states[14].

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[12] A separate state (Jharkand) was created out of Bihar in 2000. However in estimation we have used Bihar as undivided Bihar. Estimate for 2000 is thus not reported for Bihar. For the other two major states Madhya Pradesh and Uttar Pradesh the energy data have been obtained for the undivided states for the period under consideration.

To bring in population more directly we have reported the per capita CO_2 emission by states in Table 8. Comparing the ranks in terms of aggregate emission and per capita emission we find that the rank correlation between aggregate emission and the per capita emission for 1980 and 2000 are 0.612 and 0.518 respectively. The pattern of the rank has changed grossly in Uttar Pradesh, Delhi and Goa. In case of Uttar Pradesh the aggregate emission is high but so is population. Hence per capita emission is low. In case of Delhi and Goa the situation is just the opposite. Aggregate emission for Delhi and Goa is low but their populations are lower. Hence their per capita ranks are high.

Turning now to the percentage shares (Table 9), the following states' shares have declined over time: Delhi, Bihar, West Bengal and Gujarat. Assam. Goa and Kerala have remained almost constant throughout the period. The shares of the rest of the states have gone up. Although Uttar Pradesh was the highest emitter among the major Indian states in recent years, the percentage contribution of emissions of Bihar was 16.33 in 1980 and that of Uttar Pradesh was 9.09 in that year. During 1990, the contribution of Bihar was 10.30 per cent while that of Uttar Pradesh had become 12.46 per cent. In 2000 Uttar Pradesh became the highest contributor accounting for around 14 per cent of the CO_2 emission from fossil fuel in India. Plotting the percentage shares over the states in figure 4 we clearly find that the concentration of CO_2 emission has increased in case of Uttar Pradesh and Andhra Pradesh. Therefore the percentage of emission is skewed. It should be noted that, technically coal is more polluting in terms of CO_2 emission than petroleum or Kerosene. The pattern of concentration appears to suggest that states which have not been able to reduce coal consumption have become the major polluters. Since the number of such states is progressively getting smaller, therefore the main CO_2 emitters have become few with high percentage of emission. To investigate this further one can look at the correlation between aggregate consumption of different kind of fuels and aggregate emissions across states. The correlation between solid fuel and CO_2 emission for the major Indian states taken together is 0.989 while for liquid fuel it is 0.758 implying that the association with coal is stronger than that between liquid fuels.

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[13] Among the 19 major states considered rank of Madhya Pradesh is 14 and that of Uttar Pradesh is 17 in terms of per capita income for 1999.

[14] It should be noted that 'finding determinants of emissions' is really a misnomer here as the emissions themselves are estimates generated from a set of other variables. Strictly speaking it is the usage pattern of these other variables ('the fuel usage pattern of the Indian states') whose determinants get highlighted by such an exercise.

Let us now turn to the state wise trend in emission. Table 10 provides the state wise least square growth rates over time. Growth rates between 1980 and 2000 had a wide fluctuation. The lowest growth rate has been recorded for West Bengal (3.66%) while the highest was Himachal Pradesh (11.63 %). The states like Andhra Pradesh, Orissa, Karnataka, Rajasthan and Uttar Pradesh also have high growth rates. Interestingly all the growth rates are significant. Further the all India growth rate was 5.86 per cent. The following states had emission above the Indian average: Andhra Pradesh, Haryana, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh. Besides least square growth rates covering the data relating to the entire time span, end-point decadal growth rates (both linear and compound annual) have also been considered to identify changes in the pattern of emission growth over decades at the state level (See Table 11). As far as the growth rates over the decades are concerned the rank correlation between the growth rates in the decades of the 1980s and 1990s, is about 0.65 implying that some states whose CO_2 emission had grown relatively faster in the earlier decade did not grow very fast later on and vice versa. India's CARG was 6.75 during 1980 to 1990 which had dropped to 5.08 during the next decade and the decline has been more or less evenly distributed over the states. A notable exception is Assam. Whose growth rate became negative in 1990s though it was quite high (almost 10% CARG and around 15 % linear) in 1980s. Another exception is West Bengal for which the CARG during 1980s was 2.81 per cent. This became 4.41 during 1990s. In case of linear growth in CO_2 emission for West Bengal it was 3.2 per cent during 1980s which shot up to 5.4 per cent during 1990s. It may be noted that the percentage contribution of petroleum products of West Bengal as compared to other major states of the country has gone down over the decades from 1980 to 2000, while the share of coal consumption for this state remained stable during this period. The significant declines were for the states like Jammu& Kashmir, Himachal Pradesh, Punjab, Haryana, Assam, Gujarat, Madhya Pradesh and Andhra Pradesh. The situation is more or less similar if end-point linear growth rate is considered instead of CAGR. The end-point growth rate for India was 9.21 during 1980s, which fell to 6.41 during 1990s. Significant decline in end-point growth rates can be observed for most of the states except West Bengal, Goa, Kerala and Tamil Nadu. Consumption pattern of the solid and liquid fuels by states reveals that during 1980 to 2000, consumption of petroleum products were high for the states like Maharashtra, Gujarat, Uttar Pradesh, Andhra Pradesh and Tamil Nadu, whereas coal consumption was high in Uttar Pradesh, Bihar, West Bengal, Madhya Pradesh and Andhra Pradesh. Also the pattern of growth is more or less same for least square growth rates and end-point growth rates (both compound and linear). Like least square growth rates end-point growth rates for most of the states are higher than the All India growth rate.

4.2.2 The Entire Panel

In this section we will pool together the time series and the cross section components of the data to conduct a simple scatter plot analysis on the resultant panel. Let us first turn to the relationship between emissions and the level of development of the states[15]. The conjecture in the literature that has acquired a lot of prominence is that the relationship is inverted U-shaped (The Environmental Kuznets Curve (EKC) conjecture)[16]. Figure 5 indeed shows that such a conjecture is true for the Indian states to a large extent. Looking at panel (a) of the figure there appears to be two bend back points in the inverted U-shape. Or rather it appears that there are two distinct EKCs for India one that is expected to bend back at a substantially higher level of emission than the other. On careful scrutiny of the points on the steeper curve we find that they belong to the following states: (undivided) Bihar, Orissa, (undivided) Madhya Pradesh and Andhra Pradesh. These are the states where India's major steel plants are located. Steel plants consume a lot of coal, which is one of the main ingredients in estimating the levels of emission. This has made their emission levels disproportionately high, compared to their incomes. An important point needs to be made here. The location of steel plants in India is entirely dictated by the availability of raw materials (mainly iron ore and coal) and has nothing to do with the level of development of the state. On the other hand, the steel plants have very little impact on the overall development of the states. The linkages between the setting up of steel plants and income generation have failed to materialize in India. Almost all of these states (except, to an extent Andhra Pradesh) are poor. It would thus be logical to assume that the relationship between incomes and emissions is purely spurious for these states.

Eliminating these states (Panel (b)) we get a single inverted U curve for the panel. It is observed from Table 12 that bend-back income is Rs. 18444. The states whose observations constitute the bend-back are: Delhi and Goa. The scatter is thick on the rising portion. As we approach the bend back and beyond, points become sparse. Thus clearly, though the bend back is a reality, most states are still in the upward sloping part of the curve. For them emission is rising with income.

The relationship with respect to income can be extended to the fuel usage pattern as well. Here a distinction has to be made between domestic usage of fuel and industrial usage of fuel. The second component of fuel usage has nothing to do with the level of income of consumers living in the respective states[17].

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[15] Here we do the analysis with respect to the economic development of the states only. As pointed out by a referee this could be extended to the level of human development of states as well. For this the logical link of emissions with life- expectancy and education will have to be carefully formulated. That can be an interesting exercise to do in future.

[16] Holtz-Eakin and Seldon (1995) observed this type of inverted U shaped relationship in case of CO_2 emission. Further, Aldy (2004) has used state-level CO_2 data for the US from 1960 to 1999 to estimate pre-trade (production-based) CO_2 EKCs and post trade (consumption-based) CO_2 EKCs.

[17] As pointed out by a referee, industrial usage may also have a relationship with the per capita income of the people living in a state in the sense that with income people's consciousness regarding pollution increase forcing abatement by industries.

However the first one does have a link at least in India: if we travel up from the lowest income levels to the highest income levels we find that there are at least three stages (i) where people neither use coal nor petrol/LPG (ii) where people gradually shift to coal and uses small amounts of petrol/LPG and (iii) where people do not use coal at all but depend entirely on petrol/LPG[18]. Does the panel reflect this private usage pattern? Panel (a) and (b) of Figure 6 shows that indeed something like this happens as far as coal is concerned. It is evident from the points marked in panel (b) of Figure 6 that people do shift from coal to other fuels as income per capita goes beyond a level. On the other hand as far as liquid fuel is concerned, the scatter is monotonically increasing as expected (panel (c) and (d)). Thus it appears that the inverted U-shape of CO_2 – per capita income scatters in Figure 5 are entirely caused by the usage pattern of coal in India[19].

5. Conclusions

This paper estimates the magnitude of CO_2 emissions of the Indian states from 1980 to 2000. The estimates show that of the several sources from which CO_2 is emitted coal is by far the most important for India. Liquid fuels come second. Though we did not have data for distinguishing the consumption of coal for domestic usage and that for industrial purposes, the scatter plot between coal and income appears to suggest that a large majority of people have not yet been able to shift from coal to petrol/LPG for personal usage. Income, especially through its effect on the consumption of coal appears to be important in dictating the estimates. However by no means can we discount other determinants like population. Also the relationship between income and CO_2 emission for Indian states (eliminating the states having major steel plants) exhibits an inverted- U curve when using panel data estimates. Finally, a comparison of our result with the results from ORNL shows that our result has an upward bias, although the reason behind this remained unexplored. But the movement of the two series over time definitely indicates the consistency of estimation of CO_2 emission at the state level.

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[18] The phenomenon can be more clearly laid out as follows: When incomes are very low people use stray wood, which is available free of cost, as cooking fuel and travel very occasionally so that their LPG usage is nil and their usage of petrol is very small. As income increases fuel wood is gradually replaced by coal, which has to be bought, and traveling by public transport rises. So we would expect an interval where coal usage gradually rises (so does petrol usage but to a smaller extent). There is still no LPG usage. As income rises further coal is replaced by LPG progressively and public transport by private cars. Coal usage becomes nil after a threshold level of income is reached and LPG/Petrol usage rises rapidly. In India all these categories of individuals are simultaneously present – in large numbers as well.

[19] As we have already stated, one of the limitations of our analysis is that we could not consider all the fuels causing CO_2 emissions. As pointed out by a referee of this journal, for Delhi, whose observations constitute the bend –back of the inverted U shaped curve there has been a rise in CNG use in recent years. It may well have happened that Delhi would have moved to the upward sloping zone if they had not shifted to CNG. However CNG's contribution to CO_2 is substantially smaller than that of petrol so Delhi has definitely cut down on CO_2 emissions relative to its income level compared to other states.

Appendix I: Data Source by type of Fuels

Variable	Data Source	Remarks
Solid Fuels		
Coal	CMIE 'Energy, May,2005' (pp 285-287)	No consumption data available in case of Goa.
Liquid Fuels		
Liquified Petroleum Gas	CMIE 'Energy, May,2005' (pp 52-70)	
Naptha	-Do-	No consumption in J&K, Himachal Pradesh, Haryana & Punjab (for some years).
Motor Gasolene	-Do-	
Kerosene	-Do-	
High Speed Diesel Oil	-Do-	
Light diesel Oil	-Do-	
Furnace Oil	-Do-	
Low Sulphur Heavy Stock	-Do-	No consumption for J&K, Himachal Pradesh, Delhi, Rajasthan and Karnataka during early 80's and from mid 90's to end of that decade for West Bengal.

Appendix -II

CO_2 Emissions from Cement Manufacturing: A Test Case

The basic data required for estimation of CO_2 emission from cement manufacturing for the Indian states are the state level annual data on cement production. But time series data on cement production for Indian states are scanty. These data for some latest year are available with Central Statistical Organization, Industrial Statistical Wing of the Government of India. So the exercise of estimating CO_2 emission from cement manufacturing for the Indian states has been done for the terminal period 2000.

Methodology

As cement manufacturing uses essentially 100% of the calcium oxide obtained from burning the calcium carbonate during calcinations, the amount of calcium oxide content in the finished cement is a good measure of the amount of CO_2 released during production (Griffin 1987). To determine the amount of CO_2 released from cement manufacturing, one needs to know how much cement was manufactured, the average calcium oxide content per unit of cement, and a factor to convert the calcium oxide content into carbon dioxide equivalents. Cement production data published by the U.S. Bureau of Mines are currently reported in thousand short tons, but before 1970 the data were reported in barrels. To ensure consistent units throughout the 1950-92 record, two equations were used to convert cement production estimates to units of metric tons. Cement production before 1970 was calculated by using cement production (in metric tons) = 0.17055 × quantity of cement produced (in barrels), where 0.17055 is the metric-ton equivalent for a barrel. After 1969, net cement production was calculated by using cement production (in metric tons*)* = 0.90718474 × quantity of cement produced (in short tons*)*, where 0.90718474 is the metric-ton equivalent for a short ton. The amount of CO_2 produced from cement production was calculated by usingCO_2 production (in metric tons of C) = *0.136* metric tons of C per metric ton cement × quantity of cement produced (metric tons) This conversion factor was obtained by dividing the molar mass of carbon by the molar mass of calcium oxide and multiplying this quotient by the average fraction of calcium oxide contained in cement: (12.01 g C/mole $CaCO_3$ ÷ 56.08 g CaO/mole $CaCO_3$) × 0.635 g CaO/g cement = 0.136 g C/g cement The consensus that 63.5% of the typical cement in the world is composed of calcium oxide is based on the opinions of experts consulted in the field, as well as inspection of composition data by type and country (Griffin,1987).

CO_2 Emission from cement manufacturing in India

The results are presented in Table A1. It can be seen that for 2000 the total CO_2 emission arising out of cement manufacturing was to the tune of 10387 '000M.T. of carbon. For the state level CO_2 emission from cement manufacturing Andhra Pradesh topped the list, followed by Rajasthan, Madhya Pradesh and Gujarat. The total CO_2 emission for India in 2000 (from fossil fuel and cement manufacturing) became 334431 '000 M.T. of carbon of which contribution of CO_2 from cement manufacturing is 3.11 per cent which is in conformity with the percentage of CO_2 emission from cement manufacturing (3 per cent) at the global level.

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Table 1: CO_2 Emission by top 25 nations, 2003

Rank	Nation	(000 M.T. of C)
1	UNITED STATES OF AMERICA	1580175
2	CHINA (MAINLAND)	1131175
3	RUSSIAN FEDERATION	407593
4	INDIA	347577
5	JAPAN	336142
6	GERMANY	219776
7	CANADA	154392
8	UNITED KINGDOM	152460
9	REPUBLIC OF KOREA	124455
10	ITALY (INCLUDING SAN MARINO)	121608
11	MEXICO	113542
12	ISLAMIC REPUBLIC OF IRAN	104112
13	FRANCE (INCLUDING MONACO)	102065
14	SOUTH AFRICA	99415
15	AUSTRALIA	96657
16	UKRAINE	85836
17	SPAIN	84401
18	POLAND	83121
19	SAUDI ARABIA	82530
20	BRAZIL	81445
21	INDONESIA	80544
22	THAILAND	67131
23	TAIWAN	62720
24	TURKEY	60057
25	ALGERIA	44672

Source: Oak ridge National Laboratory, United States.

Table 2: CO2 Emission from fossil fuels by different sources in India and world

Percentage

Year	India					World				
	Solid	Liquid	Gas	Cement	Gas Flaring	Solid	Liquid	Gas	Cement	Gas Flaring
1980	72.75	23.66	0.72	2.54	0.34	36.70	45.55	13.88	2.25	1.61
1981	71.92	23.69	0.77	2.77	0.85	37.30	44.48	14.64	2.34	1.24
1982	71.62	23.50	1.10	2.82	0.96	38.82	42.99	14.58	2.36	1.25
1983	72.12	22.72	1.22	2.93	1.00	39.01	42.80	14.60	2.45	1.14
1984	70.67	23.53	1.39	3.25	1.17	39.50	41.83	15.30	2.42	0.97
1985	70.39	23.55	1.47	3.37	1.22	41.06	40.27	15.38	2.41	0.90
1986	70.61	23.02	1.97	3.46	0.95	40.89	41.02	14.82	2.45	0.82
1987	71.23	22.26	2.08	3.32	1.11	40.85	40.29	15.58	2.50	0.77
1988	71.67	21.58	2.14	3.39	1.23	40.37	40.55	15.69	2.55	0.84
1989	70.56	22.04	2.39	3.52	1.49	40.18	40.58	16.01	2.57	0.66
1990	70.29	21.83	2.82	3.60	1.47	38.71	41.38	16.69	2.56	0.65
1991	70.67	21.67	2.96	3.49	1.20	36.92	42.43	17.35	2.58	0.70
1992	69.63	23.11	2.90	3.22	1.15	37.33	41.40	17.95	2.73	0.59
1993	70.51	22.26	2.80	3.32	1.11	36.30	41.98	18.24	2.87	0.60
1994	70.19	22.24	3.80	3.30	0.47	36.70	41.65	18.09	2.97	0.59
1995	69.39	22.98	3.89	3.40	0.33	37.10	41.28	17.99	3.06	0.56
1996	67.55	23.46	5.01	3.73	0.25	36.83	41.07	18.46	3.09	0.55
1997	69.18	23.11	3.51	3.89	0.31	36.22	42.05	18.04	3.12	0.55
1998	67.18	24.03	4.50	3.98	0.31	34.72	42.97	18.70	3.14	0.47
1999	68.52	22.94	4.20	4.06	0.28	33.59	43.02	19.56	3.33	0.48
2000	67.56	23.92	4.15	4.08	0.29	32.72	43.68	19.75	3.39	0.46
2001	68.10	22.99	4.13	4.49	0.29	34.17	42.43	19.60	3.45	0.35
2002	67.71	23.18	4.20	4.66	0.25	35.14	41.26	19.66	3.61	0.34
2003	68.61	22.26	4.15	4.81	0.17	35.93	40.82	19.20	3.77	0.29

Source: Oak ridge National Laboratory, United States.

Table 3: Sources of CO_2 Emission

Greenhouse Gas	Natural Sources[1]	Human Activity
Carbon Dioxide	Respiration Fires Fires Rotting wood Decomposition of organic material in soil	Burning fossil fuels for transportation & commercial energy Tropical deforestation Cement manufacture Other land use changes

Notes: 1. Houghton, John, 1994, *Global Warming, The Complete Briefing*, Lion Publishing, 192p.

Source : The effect of population on global climate change (Tonalee Carlson Key, http://www.cnie.org/pop/intros/globalclimate1.htm)

Table 4: List of the primary and secondary fuels

Gas Fuels	
Primary Gas Fuels	**Secondary Gas Fuels**
Natural Gas	Gas works Gas
	Coke Oven Gas
	Refinery Gas
Liquid Fuels	
Primary Liquid Fuels	**Secondary Liquid Fuels**
Crude Petroleum	Aviation Gasoline
Natural Gas Liquids	Plant Condensate
	Gas Diesel oil
	Feedstock
	Jet Fuel
	Kerosene
	Liquefied Petroleum Gas
	Motor Gasoline
	Natural Gasoline
	Residual Fuel Oil
	Secondary Non-Energy Liquid Fuels
	Bitumen/Asphalt
	Lubricants
	Napthas
	Petroleum Coke
	Other Petroleum Products
	Petroleum Waxes
	White Spirit/Industrial Spirit
Solid Fuels	
Primary	**Secondary**
Coal	Lignite Briquette
Lignite/Brown Coal	Hard Coal Briquette
Oil Shale	Brown Coal Coke
Peat	Peat Briquette
	Gas Coke

Source : United Nations Energy Statistics Database used in calculating CO_2-emission estimates.

Table 5: Estimated CO_2 Emission of India in '000 metric ton of Carbon

Year	ORNL Estimates	Our Estimates	Index on ORNL Estimates [Base 1980=100]	Index on Our Estimates [Base 1980=100]
1980	92060	102818	100.00	100.00
1981	98167	112568	106.63	109.48
1982	104246	121103	113.24	117.78
1983	112913	127393	122.65	123.90
1984	116208	132745	126.23	129.11
1985	127151	144549	138.12	140.59
1986	136776	154763	148.57	150.52
1987	144873	165916	157.37	161.37
1988	155917	178096	169.36	173.21
1989	168741	189378	183.29	184.19
1990	174918	197492	190.00	192.08
1991	188203	212969	204.44	207.13
1992	202114	221488	219.55	215.42
1993	210579	233858	228.74	227.45
1994	225921	246739	245.41	239.98
1995	238450	263852	259.02	256.62
1996	262786	277572	285.45	269.96
1997	268128	288130	291.25	280.23
1998	276821	297989	300.70	289.82
1999	280853	303845	305.08	295.52
2000	278432	324044	302.45	315.16
CAGR [1980-2000]	5.69	5.91		

Note: CAGR is the compounded annual growth rate.

Table 6: Estimates of State Level CO_2 Emissions of India (000 Metric tons of Carbon)

Year	J&K	HP	Punjab	Haryana	UP	Rajasthan	Delhi	Bihar	Orissa	WB
1980	168.29	88.75	2377.12	1258.36	9343.07	1578.61	2791.54	16785.77	3787.62	11499.33
1981	183.15	93.77	3114.93	1651.86	10338.96	1696.24	3113.24	18632.27	3789.09	12501.49
1982	177.70	107.79	3332.82	2009.99	10824.98	2020.46	3673.14	19639.46	3568.06	12753.50
1983	190.05	109.47	3694.72	2207.57	12455.89	2734.82	3657.65	18779.63	4049.46	12313.33
1984	221.24	118.68	4026.68	2817.07	14090.17	3131.88	3890.40	16956.36	4461.80	11663.23
1985	243.01	125.38	5185.40	2788.61	16437.54	2897.46	3772.78	18854.36	4284.94	12848.32
1986	342.01	153.42	5638.13	2860.82	17317.68	3039.37	4559.56	18429.89	4107.03	12742.42
1987	344.31	177.50	6109.50	3229.41	20510.24	3322.36	4696.66	18757.25	5516.50	13307.97
1988	277.55	222.71	5370.01	3192.99	23014.18	3758.98	4881.27	20135.12	6380.52	14190.19
1989	443.32	228.78	6225.66	3698.06	24423.24	4770.77	4727.44	20552.89	7677.80	14268.27
1990	455.46	316.68	6544.86	3307.49	24603.24	4573.60	5090.58	20345.27	8424.19	15175.41
1991	453.78	301.62	6830.78	3983.13	26963.81	5746.56	5500.19	20383.78	9122.22	17909.15
1992	373.20	343.48	7629.28	4625.08	29599.19	5830.91	5696.11	22025.59	9527.44	17197.93
1993	365.88	331.76	8572.63	3786.60	31449.68	6251.62	6101.74	20414.13	9557.16	18439.54
1994	381.16	422.39	8235.86	4262.36	31961.24	6427.45	6288.66	20313.46	10442.74	20435.90
1995	467.81	498.16	8646.74	4068.34	35823.36	7058.52	5691.09	21261.20	12180.41	21432.42
1996	474.93	547.55	9408.62	4901.59	38313.29	7903.29	5625.17	22867.63	12606.97	20984.92
1997	506.74	549.65	10434.64	5007.92	40284.56	7763.89	6143.62	18291.14	14175.73	19212.73
1998	569.95	488.22	9392.09	5532.66	40046.38	7960.23	4018.43	29905.87	13546.24	17753.24
1999	588.90	682.98	11012.55	5250.84	44122.21	7562.35	5129.22	23184.21	15957.24	23457.05
2000	696.48	659.12	10845.72	5460.46	44268.30	8929.33	6033.84	..	16172.30	23363.71
Mean Emission	377.38	312.75	6791.85	3614.34	26009.11	4998.03	4813.44	20325.76	8539.78	16354.76
Rank of Mean	18	19	10	14	1	12	13	4	9	6

J&K: Jammu & Kashmir; HP: Himachal Pradesh; UP: Uttar Pradesh; Raj: Rajasthan; WB: West Bengal;

Table 6(Contd.) : Estimates of State Level CO_2 Emissions of India (000 Metric tons of Carbon)

Year	Assam	Gujarat	Mah	Goa	MP	AP	Kar	Kerala	TN	Others
1980	589.84	7501.63	10564.23	234.43	9890.58	4940.93	1586.15	946.09	4540.14	12345.52
1981	682.14	8875.51	11166.82	317.32	10501.97	6626.26	1859.93	1011.18	4913.12	11498.67
1982	657.02	9894.43	11534.16	316.48	11656.09	7006.99	1844.65	991.93	5384.90	13708.95
1983	622.91	10570.49	12544.69	338.25	12753.70	8051.43	2208.01	1052.42	5577.67	13480.59
1984	668.75	10705.50	13382.98	335.74	14390.89	8367.49	2376.71	1227.19	6321.76	13590.70
1985	856.71	11536.44	16059.59	382.62	15065.49	9818.61	2754.51	1546.59	7263.85	11827.08
1986	956.76	12442.96	17613.07	406.07	17388.37	11027.98	3508.02	1425.41	7915.64	12888.26
1987	1043.83	13644.80	19243.15	398.53	18206.35	10830.40	3794.35	1539.90	8253.88	12988.62
1988	1252.72	13893.88	19564.25	391.00	21916.93	12329.67	4392.34	1719.70	9424.96	11787.20
1989	1257.11	14355.40	21449.69	409.42	24574.08	13797.34	4265.30	1828.33	9329.52	11095.76
1990	1470.40	15081.90	22660.12	442.07	25945.04	16117.29	4569.42	1697.10	9808.62	10863.01
1991	1329.33	15776.39	24651.46	499.00	27238.76	19429.14	4708.82	2059.20	10550.83	9531.41
1992	1245.81	15840.44	25387.39	503.19	27406.21	20335.24	5104.21	2328.37	12409.68	8079.03
1993	1093.23	16255.28	28229.36	512.40	31345.35	23159.41	5767.29	2344.91	11802.27	8078.20
1994	1134.67	16214.27	29056.75	545.05	33412.05	24102.55	6232.59	2208.24	12298.76	12362.49
1995	1298.35	17375.52	32216.88	589.42	35096.14	27312.28	11423.18	4149.56	12837.53	4424.89
1996	1277.21	17786.82	34255.33	578.54	33988.91	28383.31	7941.59	2628.74	13765.18	13332.01
1997	1078.78	18932.99	34626.23	617.05	35698.32	29787.55	7808.47	2925.33	15663.17	18621.88
1998	923.27	18511.16	33120.79	532.49	33601.08	28364.70	8211.81	2710.80	15384.18	27415.73
1999	1205.10	20066.85	35051.86	642.17	37790.15	29475.08	8504.22	2889.45	15069.19	16203.07
2000	1097.00	18461.46	35595.43	652.22	39279.35	30126.02	9059.61	3034.19	17584.85	43712.56
Mean Emission	1035.28	14463.05	23236.87	459.21	24625.99	17589.98	5139.10	2012.60	10290.46	14182.65
Rank of Mean	16	7	3	17	2	5	11	15	8	..

Mah: Maharashtra; MP: Madhya Pradesh; AP: Andhra Pradesh; Kar: Karnataka; TN: Tamil Nadu; Others : Remaining States and uTs.

Table 7: Source wise Percentage Contribution of CO_2 Estimation by States

States		LPG	Naptha	MG	Kerosene	HSDO	LDO	FO	LSHS	Coal	Total C
Jammu & Kashmir	1980	0.995	0.000	6.468	13.433	40.796	2.488	0.995	0.000	34.825	100.000
	2000	7.814	0.000	8.415	18.032	29.211	0.601	0.841	0.481	34.605	100.000
Himachal Pradesh	1980	0.943	0.000	4.717	15.094	41.510	0.943	3.774	0.000	33.018	100.000
	2000	6.478	0.000	6.097	6.351	37.346	0.635	2.922	2.159	38.011	100.000
Punjab	1980	0.247	0.000	2.923	5.424	21.027	1.198	7.291	6.727	55.163	100.000
	2000	2.447	0.000	3.227	2.617	16.065	0.278	1.629	4.477	69.260	100.000
Haryana	1980	0.532	0.000	2.196	4.724	20.692	2.329	0.000	1.996	67.531	100.000
	2000	3.511	0.000	3.450	2.913	33.518	0.951	0.000	5.857	49.800	100.000
Uttar Pradesh	1980	0.260	2.536	1.022	3.531	9.956	0.905	2.599	0.000	79.192	100.000
	2000	1.441	2.400	1.106	2.663	8.761	0.320	0.653	0.480	82.176	100.000
Rajasthan	1980	0.265	6.099	2.493	6.789	29.330	2.440	3.394	0.000	49.190	100.000
	2000	2.522	6.151	2.532	4.819	23.994	0.534	1.725	0.375	57.347	100.000
Delhi	1980	1.410	0.000	3.989	3.659	11.307	0.840	3.479	0.000	75.316	100.000
	2000	6.327	0.000	7.882	2.914	16.984	1.082	0.097	0.500	64.214	100.000
Bihar[a]	1980	0.060	0.439	0.304	1.127	2.619	0.339	1.566	0.195	93.351	100.000
	2000	0.575	0.003	0.562	2.889	5.781	0.293	0.844	0.376	88.677	100.000
Orissa	1980	0.066	1.348	0.486	1.636	3.979	0.088	3.272	0.155	88.970	100.000
	2000	0.357	0.248	0.580	1.739	4.023	0.083	1.010	0.005	91.955	100.000
West Bengal	1980	0.138	0.641	0.743	2.920	5.468	0.815	2.716	0.175	86.385	100.000
	2000	1.297	1.559	0.656	2.992	6.819	0.548	1.018	0.000	85.110	100.000
Assam	1980	0.284	0.000	4.258	14.620	22.569	3.123	9.085	3.833	42.228	100.000
	2000	8.548	2.366	5.266	21.218	28.773	0.229	3.587	1.832	28.181	100.000

Table 7(Cond.) : Source wise Percentage Contribution of CO_2 Estimation by States

States		LPG	Naptha	MG	Kerosene	HSDO	LDO	FO	LSHS	Coal	Total C
Gujarat	1980	0.368	5.078	1.362	4.397	7.723	3.281	6.172	11.462	60.156	100.000
	2000	1.950	10.381	2.580	3.914	12.213	0.939	2.576	6.100	59.347	100.000
Maharashtra	1980	1.070	2.988	2.172	6.515	10.889	1.894	8.520	5.207	60.746	100.000
	2000	2.371	2.350	2.209	3.592	9.564	0.774	2.728	2.613	73.800	100.000
Goa	1980	0.357	21.786	3.214	5.000	26.786	1.071	41.786	0.000	0.000	100.000
	2000	4.108	38.383	5.520	3.594	28.626	0.513	19.255	0.000	0.000	100.000
Madhya Pradesh	1980	0.102	0.110	0.457	1.608	4.842	0.068	1.414	0.000	91.399	100.000
	2000	0.616	0.198	0.652	1.358	4.139	0.117	1.089	0.040	91.789	100.000
Andhra Pradesh	1980	0.491	1.169	1.271	5.304	15.115	0.593	3.999	0.000	72.057	100.000
	2000	1.417	1.142	1.348	1.773	9.202	0.106	1.092	0.367	83.553	100.000
Karnataka	1980	0.845	5.384	5.384	12.352	28.293	0.792	9.079	0.000	37.872	100.000
	2000	3.382	1.405	4.002	5.009	19.916	0.240	4.094	1.201	60.751	100.000
Kerala	1980	0.619	16.903	7.788	11.504	31.150	0.973	19.204	5.664	6.195	100.000
	2000	7.588	20.337	9.189	8.444	35.375	0.110	6.595	8.885	3.477	100.000
Tamil Nadu	1980	0.590	8.483	2.158	6.639	18.976	0.959	18.773	0.018	43.404	100.000
	2000	3.066	3.047	2.781	3.461	16.112	0.229	5.285	2.247	63.772	100.000
Others	1980	0.034	-0.258	0.258	0.373	0.902	0.061	0.061	0.007	98.562	100.000
	2000	1.124	6.922	0.383	1.718	1.954	0.094	2.812	0.113	84.880	100.000
All India	1980	0.330	1.893	1.239	3.443	8.424	0.914	4.190	1.684	77.883	100.000
	2000	1.809	3.014	1.706	2.929	9.834	0.370	1.962	1.301	77.076	100.000

LPG: Liquified Petroleum Gas;MG:Motor Gasoline;HSDO: High Speed Diesel Oil;LDO: Light Diesel Oil;FO: Furnace Oil;LSHS: Low Sulphur Heavy Stock;

a: Estimates of Bihar relate to 1999.

Table 8: Estimates of State Level Per Capita CO_2 Emissions of India (000 Metric Tons of Carbon)

Year	J&K	HP	Punjab	Haryana	UP	Raj	Delhi	Bihar	Orissa	WB
1980	0.03	0.02	0.14	0.10	0.09	0.05	0.46	0.24	0.14	0.21
1981	0.03	0.02	0.18	0.13	0.09	0.05	0.49	0.26	0.14	0.23
1982	0.03	0.02	0.19	0.15	0.09	0.06	0.55	0.27	0.13	0.23
1983	0.03	0.02	0.21	0.16	0.11	0.07	0.53	0.25	0.15	0.21
1984	0.03	0.03	0.22	0.20	0.12	0.08	0.54	0.22	0.16	0.20
1985	0.04	0.03	0.28	0.19	0.13	0.07	0.50	0.24	0.15	0.21
1986	0.05	0.03	0.30	0.19	0.14	0.08	0.58	0.23	0.14	0.21
1987	0.05	0.04	0.32	0.21	0.16	0.08	0.57	0.23	0.19	0.21
1988	0.04	0.05	0.28	0.21	0.17	0.09	0.57	0.24	0.21	0.22
1989	0.06	0.05	0.32	0.23	0.18	0.11	0.53	0.24	0.25	0.22
1990	0.06	0.06	0.33	0.20	0.18	0.10	0.55	0.24	0.27	0.23
1991	0.06	0.06	0.33	0.24	0.20	0.13	0.57	0.23	0.28	0.26
1992	0.05	0.06	0.37	0.27	0.22	0.13	0.57	0.25	0.29	0.24
1993	0.04	0.06	0.40	0.22	0.22	0.13	0.58	0.22	0.29	0.26
1994	0.04	0.08	0.38	0.24	0.22	0.13	0.58	0.22	0.31	0.28
1995	0.05	0.09	0.39	0.22	0.24	0.14	0.50	0.22	0.36	0.29
1996	0.05	0.10	0.42	0.26	0.26	0.16	0.48	0.22	0.36	0.28
1997	0.05	0.10	0.46	0.26	0.26	0.15	0.50	0.18	0.40	0.25
1998	0.06	0.08	0.40	0.28	0.25	0.15	0.32	0.29	0.38	0.23
1999	0.06	0.11	0.47	0.26	0.27	0.14	0.39	0.22	0.44	0.30
2000	0.07	0.11	0.45	0.26	0.27	0.16	0.44	..	0.44	0.29
Mean	0.05	0.06	0.33	0.21	0.18	0.11	0.51	0.24	0.26	0.24
Rank of Mean	18	17	5	11	12	15	1	10	7	9

J&K: Jammu & Kashmir; HP: Himachal Pradesh; UP: Uttar Pradesh; Raj: Rajasthan; WB: West Bengal;

Table 8(Contd.) : Estimates of State Level Per Capita CO_2 Emissions of India (000 Metric Tons of Carbon)

Year	Assam	Gujarat	Mah	Goa	MP	AP	Kar	Kerala	TM	Others
1980	0.03	0.22	0.17	0.23	0.19	0.09	0.04	0.04	0.09	1.19
1981	0.04	0.26	0.18	0.31	0.20	0.12	0.05	0.04	0.10	1.33
1982	0.04	0.28	0.18	0.30	0.22	0.13	0.05	0.04	0.11	1.52
1983	0.03	0.29	0.19	0.32	0.23	0.14	0.06	0.04	0.11	1.45
1984	0.03	0.29	0.20	0.31	0.25	0.14	0.06	0.05	0.12	1.42
1985	0.04	0.31	0.23	0.35	0.26	0.17	0.07	0.06	0.14	1.18
1986	0.05	0.32	0.25	0.37	0.29	0.18	0.08	0.05	0.15	1.31
1987	0.05	0.35	0.26	0.35	0.30	0.18	0.09	0.05	0.15	1.32
1988	0.06	0.35	0.26	0.34	0.35	0.20	0.10	0.06	0.17	1.08
1989	0.06	0.36	0.28	0.36	0.38	0.21	0.10	0.06	0.17	1.00
1990	0.07	0.37	0.29	0.38	0.40	0.24	0.10	0.06	0.18	0.95
1991	0.06	0.38	0.31	0.39	0.55	0.30	0.10	0.07	0.19	0.15
1992	0.05	0.37	0.31	0.39	0.54	0.30	0.11	0.08	0.22	0.13
1993	0.05	0.37	0.34	0.39	0.61	0.33	0.12	0.08	0.20	0.13
1994	0.05	0.37	0.34	0.41	0.63	0.34	0.13	0.07	0.21	0.20
1995	0.05	0.39	0.37	0.43	0.65	0.38	0.24	0.14	0.22	0.07
1996	0.05	0.39	0.39	0.42	0.62	0.39	0.16	0.09	0.23	0.20
1997	0.04	0.40	0.38	0.44	0.63	0.40	0.16	0.09	0.26	0.28
1998	0.04	0.39	0.36	0.37	0.58	0.38	0.16	0.09	0.25	0.40
1999	0.05	0.41	0.37	0.44	0.64	0.39	0.16	0.09	0.25	0.23
2000	0.04	0.37	0.37	0.44	0.66	0.40	0.17	0.10	0.28	0.62
Mean	0.05	0.34	0.29	0.37	0.44	0.26	0.11	0.07	0.18	0.77
Rank of Mean	19	4	6	2	3	8	14	16	13	..

Mah: Maharashtra; MP: Madhya Pradesh; AP: Andhra Pradesh; Kar: Karnataka; TN: Tamil Nadu; Others : Remaining States and uTs.

Table 9: Percentage Contribution of CO_2 Emission by Major States of India

Year	J&K	HP	Punjab	Haryana	UP	Raj	Delhi	Bihar	Orissa	WB
1980	0.16	0.09	2.31	1.22	9.09	1.54	2.72	16.33	3.68	11.18
1981	0.16	0.08	2.77	1.47	9.18	1.51	2.77	16.55	3.37	11.11
1982	0.15	0.09	2.75	1.66	8.94	1.67	3.03	16.22	2.95	10.53
1983	0.15	0.09	2.90	1.73	9.78	2.15	2.87	14.74	3.18	9.67
1984	0.17	0.09	3.03	2.12	10.61	2.36	2.93	12.77	3.36	8.79
1985	0.17	0.09	3.59	1.93	11.37	2.00	2.61	13.04	2.96	8.89
1986	0.22	0.10	3.64	1.85	11.19	1.96	2.95	11.91	2.65	8.23
1987	0.21	0.11	3.68	1.95	12.36	2.00	2.83	11.31	3.32	8.02
1988	0.16	0.13	3.02	1.79	12.92	2.11	2.74	11.31	3.58	7.97
1989	0.23	0.12	3.29	1.95	12.90	2.52	2.50	10.85	4.05	7.53
1990	0.23	0.16	3.31	1.67	12.46	2.32	2.58	10.30	4.27	7.68
1991	0.21	0.14	3.21	1.87	12.66	2.70	2.58	9.57	4.28	8.41
1992	0.17	0.16	3.44	2.09	13.36	2.63	2.57	9.94	4.30	7.76
1993	0.16	0.14	3.67	1.62	13.45	2.67	2.61	8.73	4.09	7.88
1994	0.15	0.17	3.34	1.73	12.95	2.60	2.55	8.23	4.23	8.28
1995	0.18	0.19	3.28	1.54	13.58	2.68	2.16	8.06	4.62	8.12
1996	0.17	0.20	3.39	1.77	13.80	2.85	2.03	8.24	4.54	7.56
1997	0.18	0.19	3.62	1.74	13.98	2.69	2.13	6.35	4.92	6.67
1998	0.19	0.16	3.15	1.86	13.44	2.67	1.35	10.04	4.55	5.96
1999	0.19	0.22	3.62	1.73	14.52	2.49	1.69	7.63	5.25	7.72
2000	0.21	0.20	3.35	1.69	13.6[illegible]	2.76	1.86	..	4.99	7.21

J&K: Jammu & Kashmir; HP: Himachal Pradesh; UP: Uttar Pradesh: Raj: Rajasthan; WB: West Bengal;

Table 9(Contd.): Percentage Contribution of CO_2 Emission by Major States of India

Year	Assam	Gujarat	Mah	Goa	MP	AP	Kar	Kerala	TN	Others	Total
1980	0.57	7.30	10.27	0.23	9.62	4.81	1.54	0.92	4.42	12.01	100.00
1981	0.61	7.88	9.92	0.28	9.33	5.89	1.65	0.90	4.36	10.21	100.00
1982	0.54	8.17	9.52	0.26	9.62	5.79	1.52	0.82	4.45	11.32	100.00
1983	0.49	8.30	9.85	0.27	10.01	6.32	1.73	0.83	4.38	10.58	100.00
1984	0.50	8.06	10.08	0.25	10.84	6.30	1.79	0.92	4.76	10.24	100.00
1985	0.59	7.98	11.11	0.26	10.42	6.79	1.91	1.07	5.03	8.18	100.00
1986	0.62	8.04	11.38	0.26	11.24	7.13	2.27	0.92	5.11	8.33	100.00
1987	0.63	8.22	11.60	0.24	10.97	6.53	2.29	0.93	4.97	7.83	100.00
1988	0.70	7.80	10.99	0.22	12.31	6.92	2.47	0.97	5.29	6.62	100.00
1989	0.66	7.58	11.33	0.22	12.98	7.29	2.25	0.97	4.93	5.86	100.00
1990	0.74	7.64	11.47	0.22	13.14	8.16	2.31	0.86	4.97	5.50	100.00
1991	0.62	7.41	11.58	0.23	12.79	9.12	2.21	0.97	4.95	4.48	100.00
1992	0.56	7.15	11.46	0.23	12.37	9.18	2.30	1.05	5.60	3.65	100.00
1993	0.47	6.95	12.07	0.22	13.40	9.90	2.47	1.00	5.05	3.45	100.00
1994	0.46	6.57	11.78	0.22	13.54	9.77	2.53	0.89	4.98	5.01	100.00
1995	0.49	6.59	12.21	0.22	13.30	10.35	4.33	1.57	4.87	1.68	100.00
1996	0.46	6.41	12.34	0.21	12.25	10.23	2.86	0.95	4.96	4.80	100.00
1997	0.37	6.57	12.02	0.21	12.39	10.34	2.71	1.02	5.44	6.46	100.00
1998	0.31	6.21	11.11	0.18	11.28	9.52	2.76	0.91	5.16	9.20	100.00
1999	0.40	6.60	11.54	0.21	12.44	9.70	2.80	0.95	4.96	5.33	100.00
2000	0.34	5.70	10.98	0.20	12.12	9.30	2.80	0.94	5.43	13.49	100.00

Mah: Maharashtra; MP: Madhya Pradesh; AP: Andhra Pradesh; Kar: Karnataka; TN: Tamil Nadu; Others : Remaining States and uTs.

Table 10: State Wise Least Square Growth Rates of CO_2 Estimation

State	Least Square Growth Rate	State	Least Square Growth Rate
Andhra Pradesh	9.64	Kerala	6.61
Assam	3.25	Maharashtra	6.82
Bihar	1.51	Madhya Pradesh	7.46
Delhi	3.04	Orissa	8.76
Goa	4.39	Punjab	7.14
Gujarat	4.29	Rajasthan	8.76
Haryana	6.29	Tamil nadu	6.72
Himachal Pradesh	11.63	Uttar Pradesh	8.33
Jammu & Kashmir	6.72	West Bengal	3.66
Karnataka	9.53	All India	5.86

Notes: (1) The least square growth rate is estimated by fitting a linear regression trend line to the logarithmic annual values of the log $y = \alpha + \beta t$. In this equation y is the variable and t is times. If $\beta *$ is the least square estimates of β, the average annual growth rate s obtained as [exp(β*)-1] and is multiplied by 100 to express it as a percentage (World Development Report, 1999-2000; World Bank). (2) All the "β" coefficients are significant at 5% level of significance.

Table 11: Growth Rates of CO_2 Emission by States

States	CAGR 1990-2000	Rank 1990-2000	CAGR 1980-1990	Rank 1980-1990	End-point growth 1990-2000	Rank 1990-2000	End-point growth 1980-1990	Rank 1980-1990
Jammu & Kashmir	4.34	13	10.47	6	5.29	13	17.06	6
Himachal Pradesh	7.61	1	13.57	1	10.81	1	25.68	1
Punjab	5.18	9	10.66	5	6.57	9	17.53	5
Haryana	5.14	10	10.15	8	6.51	10	16.28	8
Uttar Pradesh	6.05	6	10.17	7	7.99	6	16.33	7
Rajasthan	6.92	3	11.22	3	9.52	3	18.97	3
Delhi	1.71	17	6.19	16	1.85	17	8.24	16
Bihar[1]	1.46	18	1.94	19	-5.57	19	2.12	19
Orissa	6.74	4	8.32	11	9.2	4	12.24	11
West Bengal	4.41	12	2.81	18	5.4	12	3.20	18
Assam	-2.89	19	9.56	10	-2.54	18	14.93	10
Gujarat	2.04	16	7.23	14	2.24	16	10.10	14
Maharashtra	4.62	11	7.93	13	5.71	11	11.45	13
Goa	3.97	15	6.55	15	4.75	15	8.86	15
Madhya Pradesh	4.23	14	10.12	9	5.14	14	16.23	9
Andhra Pradesh	6.45	5	12.55	2	8.69	5	22.62	2
Karnataka	7.08	2	11.16	4	9.83	2	18.81	4
Kerala	5.98	8	6.02	17	7.88	8	7.94	17
Tamil Nadu	6.01	7	8.01	12	7.93	7	11.60	12
India	5.08		6.75		6.41		9.21	

Note : (1) For Bihar emission estimates relate to the period from 1980 to 1999.

Table 12: Points in the Panels determining Bend- Back Income

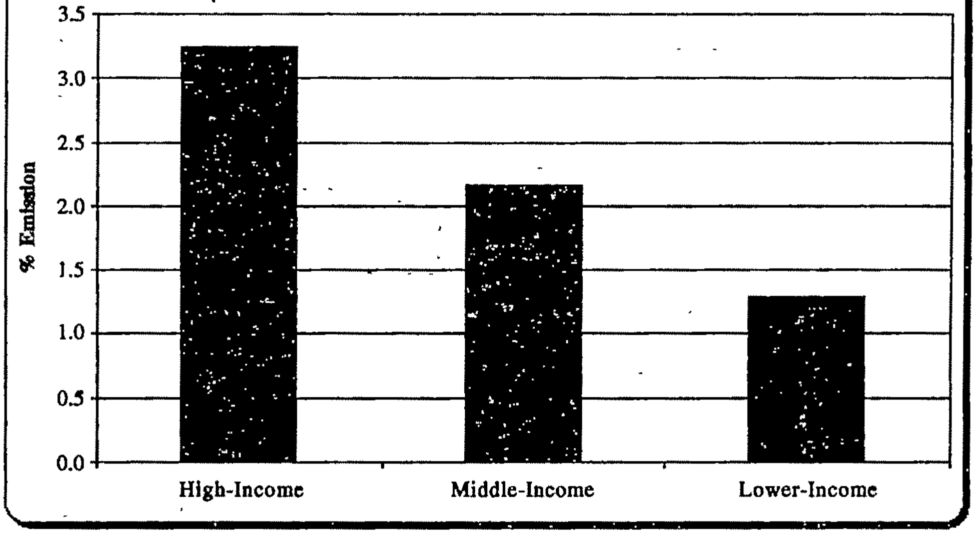
Points in the Panels	Per Capita Income(Rs.)	Per Capita CO_2(tonne)	Per Capita Coal onsumption(tonne)
a	15385	0.458	471
b	15809	0.488	511
c	15982	0.538	560
d	16971	0.552	594
e	18127	0.580	595
f	18844	0.573	572
g	19621	0.571	575
h	20755	0.550	534
I	21368	0.504	459
j	22763 (23263)	0.438	421

Note: Figure in parenthesis indicates per capita income in respect of panel (b) of Figure 6 showing per capita income and per capita coal consumption scatter.

Table : A1 Estimation of CO_2 Emission from Cement Production: 2000

State	Quantity Produced(Tonne)	CO_2('000 M.T.of C)	Rank
Andhra Pradesh	11013604	1497.850	1
Assam	276017	37.538	18
Bihar	607958	82.682	15
Goa	72144	9.812	19
Gujarat	7525869	1023.518	4
Himachal Pradesh	3204865	435.862	10
Jammu & Kashmir	343706	46.744	17
Karnataka	5824510	792.133	7
Kerala	551560	75.012	16
Madhya Pradesh	10235054	1391.967	2
Maharashtra	4452556	605.548	8
Meghalaya	51037	6.941	20
Orissa	1601290	217.775	12
Punjab	1108281	150.726	13
Rajasthan	9865794	1341.748	3
Tamil Nadu	5887876	800.751	6
Uttar Pradesh	4317757	587.215	9
West Bengal	889430	120.962	14
Jharkhand	2027060	275.680	11
Chattisgarh	6517928	886.438	5
All-India	76374296	10386.904	

Figure 1 : Per Country Percentage of CO_2 Emission by type of Economy



Note : The classification of countries is according to the classification made in the World Development Report, World Bank. The upper-middle and lower middle-income countries have been reported together as "Middle-Income" countries.

Source : Compiled from ORNL data.

Figure 2 : Movement in Estimates of CO_2 Emission of India

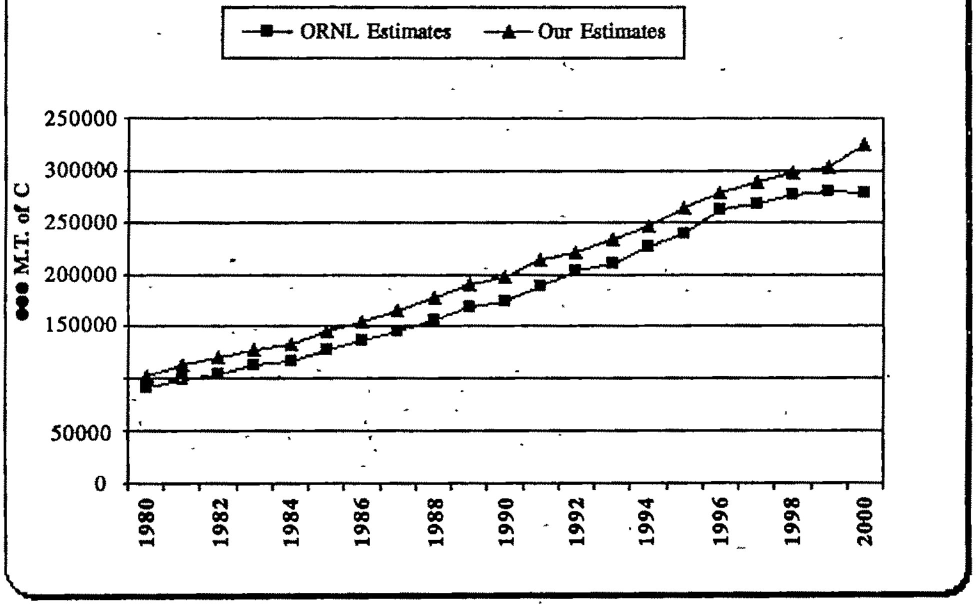


Figure 3 : 3 Mean CO_2 Emission by States : 1980-2000

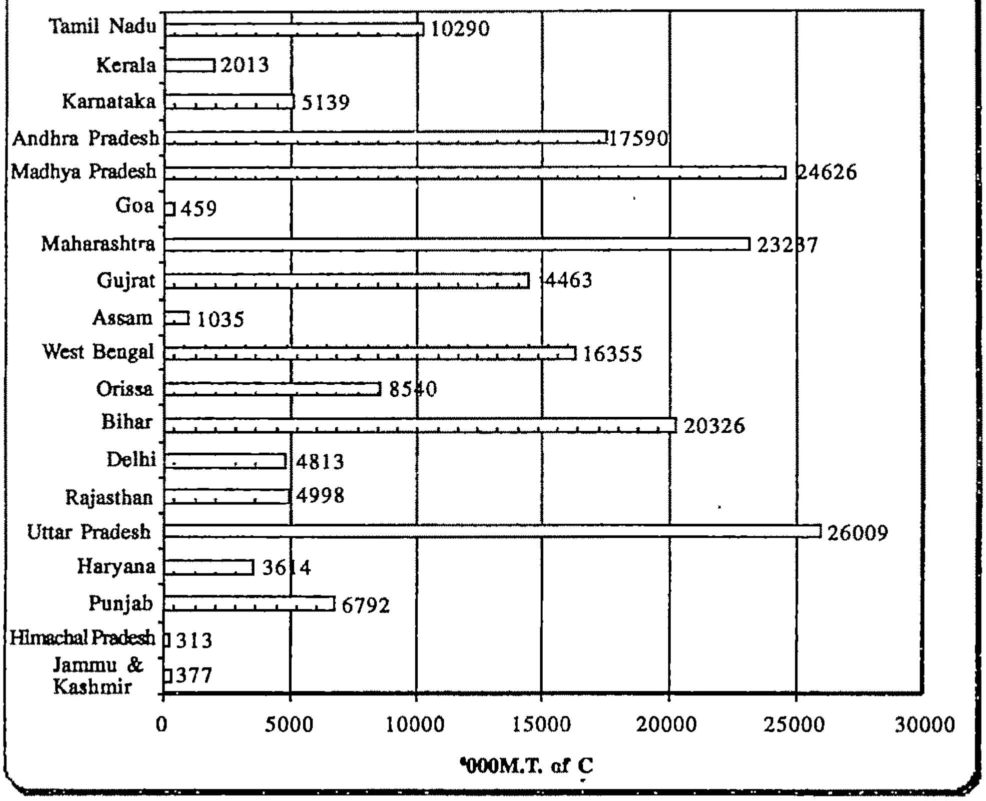


Figure 4 : Percentage Contribution of CO_2 Emission

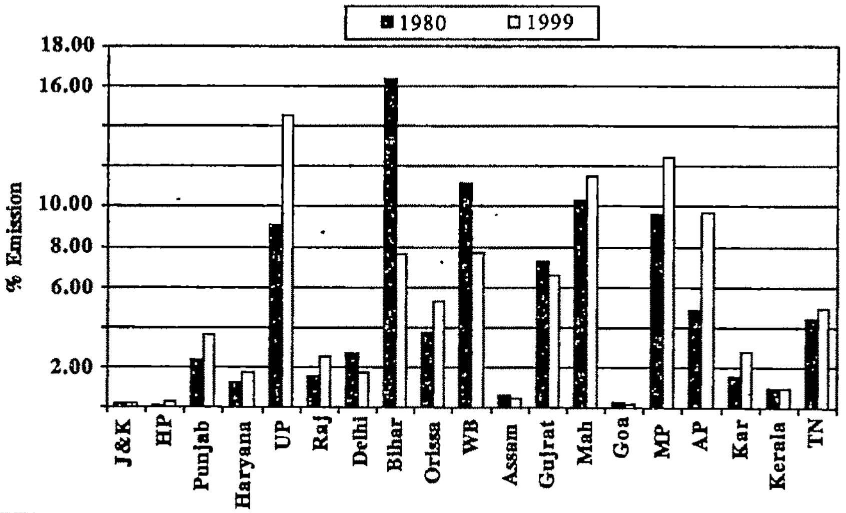
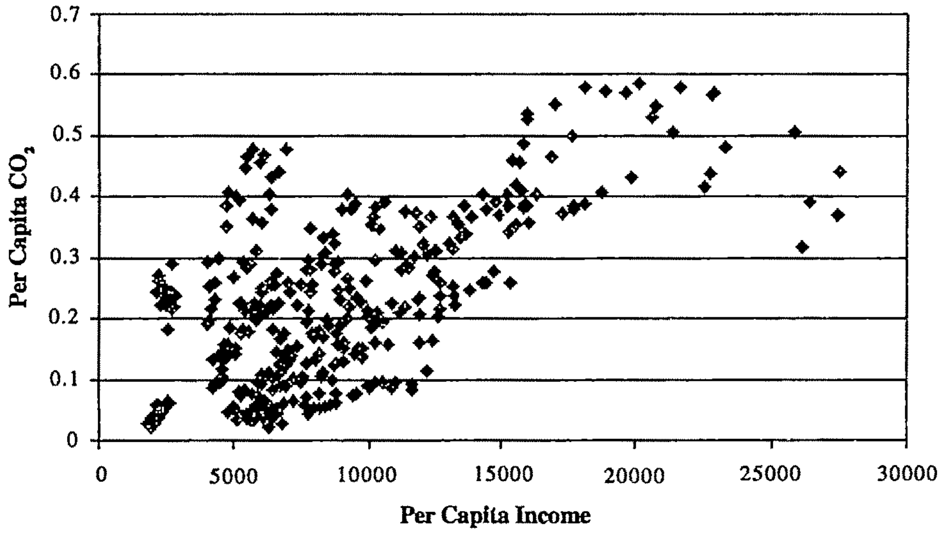
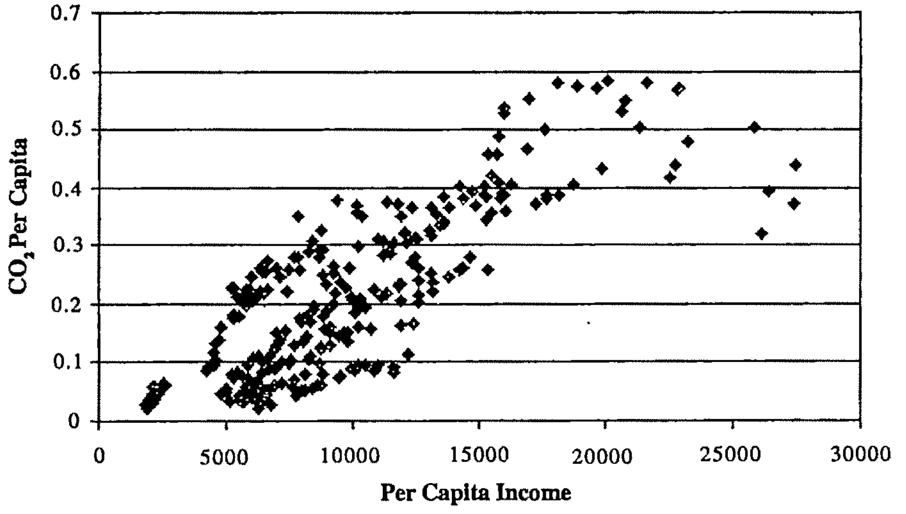


Figure 5 : Relationship between Per Capita Income and Per Capita CO_2 Emission

(a) Entire Panel

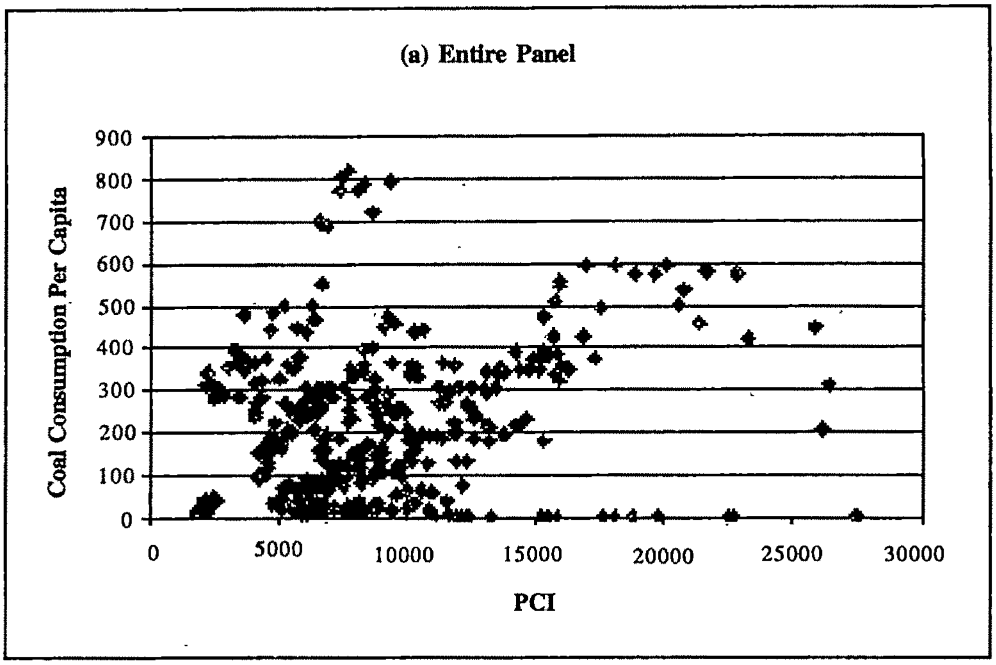


(b) : Panel data excluding Bihar, Orissa, Madhya Pradesh & Andhra Pradesh

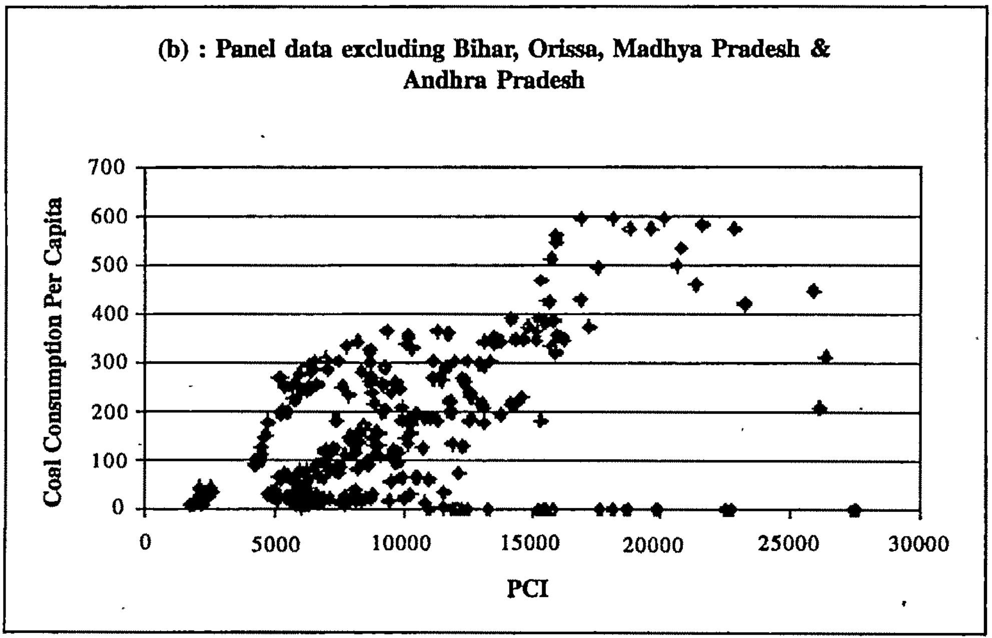


Some of the points in the panel (b) marked as a, b, c, d, e, f, g, h, i, j. These letters are missing in panel (b).

Figure 6 : Relationship between CO_2 Emission and Fuel Consumption

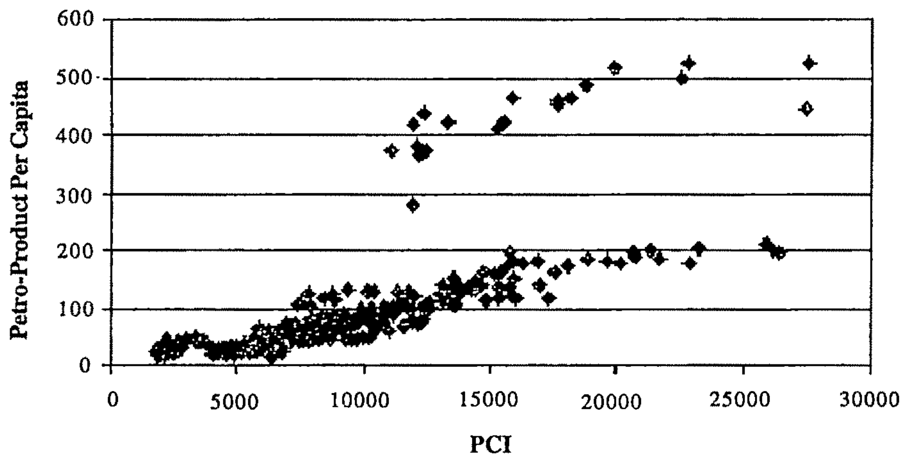


(a) Entire Panel

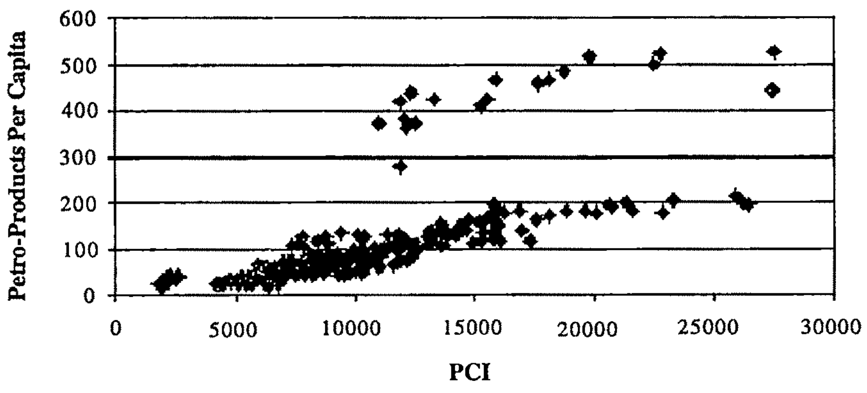


(b) : Panel data excluding Bihar, Orissa, Madhya Pradesh & Andhra Pradesh

(c) Entire Panel



(d) : Panel data excluding Bihar, Orissa, Madhya Pradesh & Andhra Pradesh



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Multiplicity of Equilibrium in Canonical and Non-Canonical Correlation Devices: An Example*

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Abstract

A correlated equilibrium for a normal form game is a mediator whose recommendations the players find optimal to follow obediently. A (direct) correlation device or a mediator however may face the multiple equilibrium problem as the obedient strategy profile may be dominated by some other Nash equilibrium in the extended game. This paper addresses the question whether it is possible to avoid this problem by considering non-canonical correlation devices. The paper presents a non-canonical correlation device to study this problem for a parametric version of the Chicken game. *JEL Classification Numbers*: C72. Keywords: Non-Canonical Correlation Devices, Multiple Equilibrium, Sunspots.

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1 Introduction

A normal form game can be played using a correlation device. The correlation device first sends private messages to each player according to a probability distribution and then the players play the original normal form game. The original game is therefore extended. In this extended game, a pure strategy for any player is a map from the set of messages to the set of pure strategies of the original game. A correlation device is called direct or canonical if the set of messages is identical to the set of pure strategies of the original game, for each player. A (direct) correlated equilibrium (Aumann (1974, 1987)) can best be described as a mediator whose recommendations the players find optimal to follow obediently. In other words, for a correlated equilibrium, the strategy of following the mediator's recommendations constitutes a Nash equilibrium in the extended game.

Consider for example, the two-player game (*Chicken*) in Figure 1*a*. Each of the two players has two strategies, namely, *A* and *P*.

	A	*P*
A	0, 0	7, 2
P	2, 7	6, 6

Figure 1*a*

The direct correlation device in Figure 1*b* is indeed a correlated equilibrium for this game, i.e., the *obedient* strategy profile (*AP*, *AP*)[1] is a Nash equilibrium in the canonical extended game.

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[1] *AP* represents the strategy of playing *A* when the recommendation is *A* and playing *P* when the recommendation is *P*.

$$\begin{array}{ccc} & A & P \\ A & \frac{1}{5} & \frac{2}{5} \\ P & \frac{2}{5} & 0 \end{array}$$

Figure 1*b*

It is well known that an extended game, extended by a (direct) correlation device, may have equilibrium other than the obedient one. First of all, *babbling* equilibrium always exists; i.e., ignoring the messages from the device altogether and playing a Nash equilibrium of the original game constitutes trivially a Nash equilibrium in any such extended game. For example, (*AA*, *PP*) is a Nash equilibrium in the extended game in the above example. There may also be non-babbling Nash equilibrium in which players do not follow the mediator's suggestions. In the above example, the profile (*PA*, *PA*) in which the players play exactly the opposite of the recommended strategies is also a Nash equilibrium in the extended game. The other equilibrium may even dominate the obedient one, i.e., by playing the other Nash equilibrium, all players can obtain a higher payoff. Indeed, in the above example, the equilibrium (*P A*, *P A*) dominates the obedient equilibrium. A direct correlation device or a mediator therefore may face this *multiple equilibrium problem*[2]. The question thus arises whether it is possible to find a device that can implement the given outcome, however, does not suffer from this multiple equilibrium problem.

One should certainly mention the recent advancement in the literature on mediated, unmediated and cheap talk here which suggests that any correlated equilibrium of a given game can be generated as an outcome of a communication process (Aumann and Hart (2003), Barany (1992), Ben-Porath (1998, 2003), Forges (1990), Gerardi (2004), Gossner (1998), Gossner and Vieille (2001), Krishna (2007), Lehrer (1996), Lehrer and Sorin (1997), Urbano and Vila (2002)). This literature uses either a complex, sophisticated communication protocol or a simple mediated talk or even an unmediated cheap talk that can replace the mediator. The central theme of this literature is that, depending on the specific set-up, any correlated equilibrium distribution can be obtained as a Nash equilibrium outcome of a communication scheme.

None of these papers however addresses the potential problem caused by the multiplicity of equilibrium. It may be easily conceived that, although a communication scheme is meant to generate one particular correlated equilibrium distribution as an equilibrium outcome, there might be multiple Nash equilibria of this communication process leading to different outcomes.

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[2] The multiple equilibrium problem is well understood in other contexts, such as, implementation theory (Palfrey (1992)), principal-agent theory (Mookherjee (1984)), differentialinformation economies (Postlewaite and Schmeidler (1986)), mechanism design (Demski and Sappington (1984)). There also exists an extensive literature on mechanism design exploring mechanisms that can uniquely implement an outcome (Ma (1988), Ma, Moore and Turnbull (1988)).

To understand this issue of multiplicity, one may take an implementation approach and ask whether a desirable correlated equilibrium distribution is fully implementable or not. One may easily construct an implementation problem in which the planner's choice function associates with every payoff matrix (a normal form game) a particular correlated equilibrium distribution of the game. Kar, Ray and Serrano (2009) show, using a parametric version of the twoperson Chicken game, that a social choice function that chooses any particular correlated equilibrium distribution does not satisfy Maskin monotonicity and therefore can not be fully implemented in Nash equilibrium. Thus, no mechanism that aims to understand a correlated distribution as the unique outcome of Nash equilibrium play can be found.

This paper tries to understand the multiple equilibrium problem by restricting the attention to a particular type of multiple equilibrium problem and a particular communication scheme. We analyse a specific two-person game (Chicken) and look at a specific form of multiple equilibrium problem, involving *disobedience.* A player adopts a *disobedient* strategy if he always chooses the action that is not recommended by the mediator. A correlated equilibrium is said to suffer from the multiple equilibrium problem if the disobedient strategy profile is also a Nash equilibrium of the extended game and it generates (weakly) higher (ex-ante, expected) payoffs for both players. We ask the question whether there exists a communication scheme, more specifically, a *non-canonical* correlation device that can implement a correlated equilibrium and does not suffer from this multiple equilibrium problem.

This exercise is clearly different from identifying an efficient correlated equilibrium (Ray (1996a)) or characterising efficiency (Myerson (2002)). The purpose is to implement an equilibrium that is clearly not optimal in the first place. One might criticise the basic motivation of this research by asking: why should the players be interested in implementing such a sub-optimal outcome? The players should always select a correlation device that does not suffer from the multiple equilibrium problem (possibly using the concepts in Ray (1996a), Myerson (2002)). One response to this fair criticism is that the correlated equilibrium that needs to be implemented could be the desire of a third party, or even the mediator.

Although any communication scheme can be thought of to avoid the multiple equilibrium problem in this context, this paper discusses a *non-direct* mediator or *non-canonical* device. A non-direct mediator or a non-canonical device is a device in which the messages are not the strategies of the original game. The paper offers a specific non-canonical structure together with a particular strategy profile of the non-canonical extended game. induces the direct correlated equilibrium in consideration.

The paper is organised as follows. The next section presents all the relevant definitions formally. Section 3 presents the basic game, the direct correlation device and the multiplicity problem. Section 4 presents an example of a noncanonical device to motivate this study. Section 5 concludes.

2 General Formulation

Fix any normal form game, G = $[N, \{S_i\}_{i\in N}; \{u_i\}_{i\in N}]$ with set of players: $N = (1,...., n)$, finite pure strategy sets: $S_1, ..., S_n$; $S = \Pi_{i\in N} S_i$, and pay-off functions: $u_1 ...., u_n$; $u_i : S \rightarrow R$, for all i.

Definition 1 *A correlation device is an* (n + 1)*-tuple,* $d = (M_1, ..., M_n, \mu)$ *where,* M_i *is a finite set of messages for player i and* μ *is a probability distributionover* M $(= \Pi_{i\in N} M_i)$*. The device selects a message profile m* $(= (m_1, ..., m_n))$ *according to* μ*, and send the private message mi to each player i.*

The extended game G_d is the game where the correlation device d selects and sends messages to the players, and then the players play the original gameG. A pure[3] strategy for player i in the game G_d is a map $\sigma_i : M_i \rightarrow S_i$ and the corresponding (ex-ante, expected) payoff is given by, $u_i^* (\sigma_1, ..., \sigma_n) = \Sigma_{m\in M} \mu (m)\mu_i (\sigma_1 (m_1) ...., \sigma_n (m_n))$.

Definition 2 *A direct correlation device is a correlation device where* $M_i = S_i$. *Such a device can be represented by a probability distribution over S.*

Definition 3 *In a given correlation device, a message profile* $m(= (m_1, ..., m_n))$*, is called a public message or a sunspot if* $\mu(m) > 0$*, and the conditional probability of* $((m_{-i}))$ *given* m_i *is* 1 *for all i. A message profile* $m(= (m_1, ..., m_n))$*, is called a semi-public message if* $\mu(m) > 0$*, and the conditional probability*[4] *of* $((m_{-i}))$ *given mi is* 1 *for some i.*

Definition 4 *A correlated equilibrium of the game G is a pair* $(d, (\sigma_1)_{i\in N})$*, where the (pure or behavioral) strategy profile* $(\sigma_1, ..., \sigma_n)$ *is a Nash equilibrium of the extended game* G_d*. A direct correlated equilibrium d of the game G is a correlated equilibrium where* $M_i = S_i$*, and* σ_i *is the identity map, for all i. The corresponding payoff to player i is given by* $\Sigma_{s\in S} d(s)\mu_i (s)$*. A correlated equilibrium distribution of the game G is a probability distribution on S which is induced by a correlated equilibrium* $(d, (\sigma_i)i_{i\in N})$.

Remark 1 *A direct correlated equilibrium can be identified with an element of* $\Delta(S)$*. Clearly, it is also a correlated equilibrium distribution, induced by itself. Let* $C(G)$ *denote the set of all correlated equilibrium distributions for the game G.*

Remark 2 *Any Nash equilibrium and any convex combination of several*

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[3] One can also think of behavioral strategies in the game G_d. A behavioral strategy for player i is a map from M_i to $\Delta (S_i)$ and the (ex-ante, expected) payoff for player i corresponding to a behavioral strategy vector is given by, $u_i^* (\sigma_1, ..., \sigma_n) = \Sigma_{m\in M}$ P(m) $[\Pi_{j\in N} \sigma_j (s_j | m_j)) u_i(s_1 ,...., s_n)\}]$. Let us however restrict ourselves to pure strategies only.

[4] Using the standard notion of conditional probability.

Nash equilibrium of a given game G, *'corresponds' to a direct correlated equilibrium. Let* $N(G)$ *denote the set of all distributions that correspond to any Nash equilibrium and let* $CONV\ (G)$ *denote any convex combination of several Nash equilibrium. Clearly,* $N(G) \subseteq CONV\ (G) \subseteq C(G)$.

Let Γ be the set of all games for which $CONV\ (G) \subset C(G)$. Let us consider games only in Γ, i.e., games for which the set of correlated equilibrium is strictly bigger than the convex hull of Nash equilibrium outcomes[5]. Also, let us consider correlated equilibrium distributions that are outside the convex hull of Nash equilibrium outcomes, i.e., $d \in C(G)\backslash CONV\ (G)$.

Definition 5 *Given any game* $G \in \Gamma$, *and a direct correlated equilibrium*[6] $d \in C(G)\backslash CONV\ (G)$ *for* G, *the set of inducible distributions,* $I(d)$, *is the set of all distributions over* S *that are induced by some (pure or behavioral) Nash equilibrium strategy profile* $(\sigma_1, ..., \sigma_n)$ *of the extended game* G_d.

Remark 3 *Clearly, any distribution in* $I(d)$ *is a correlated equilibrium for the game* G. *Thus,* $I(d) \subset C(G)$, *for any game*[7] $G \in \Gamma$, *and a direct correlated equilibrium* $d \in C(G)\backslash CONV\ (G)$.

Remark 4 *As* $d \in C(G)\backslash CONV\ (G)$ *is a direct correlated equilibrium for the game* G, *the obedient strategy profile forms a Nash equilibrium extended game* G_d. *Hence,* $d \in I(d)$.

Remark 5 *For any given game* $G \in \Gamma$, *and for any given direct device*[8] $d \in C(G)\backslash CONV\ (G)$, *the strategy profile (of the extended game) that induces a (pure or mixed) Nash equilibrium of the original game, is also a Nash equilibrium of the extended game. Particularly, for any game* $G \in \Gamma$, *and a direct correlated equilibrium* $d \in C(G)\backslash CONV\ (G)$ *for* G, $N(G) \subset I(d)$. *Note however that* $CONV\ (G) \not\subseteq I(d)$, *as not all convex combination of Nash equilibrium points can be induced from a given distribution* d. *Clearly,* $N(G) \subset I(d) \cap CONV(G)$.

Following the above remark, for any given game $G \in \Gamma$ and for any given device $d \in C(G)\backslash CONV(G)$, let us concentrate only on $I(d)\backslash\{I(d) \cap CONV(G)\}$, the set of induced correlated equilibrium other than the inducible convex combinations of Nash equilibrium of the original game.

A direct correlated equilibrium $d \in C(G)\backslash CONV(G)$ of a game $G \in \Gamma$ is said to suffer from the multiple-equilibrium problem if there exists an induced correlated equilibrium distribution $d' \in \{I(d) \cap CONV(G)\}$, such that $\Sigma_{s \in S} d'(s)\mu_i(s) \geq \Sigma_{s \in S} d(s)\mu_i(s)$ for all i, with at least one strict inequality.

We present a $2x2$ game only and a particular form of multiple equilibrium problem. Therefore the following two definitions are the only two required notions for the rest of the paper.

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[5] Certain games are hereby excluded, such as, Prisoners' Dilemma, Cournot Duopoly (see Yi (1997)). Also see Moulin and Vial (1978) in this context.

[6] This definition and the following three remarks are valid for any correlated equilibrium distribution $d \in C(G)$.

[7] This remark is valid for any game G.

[8] This remark is valid for any canonical or non-canonical device d.

Definition 6 *For a 2x2 game* $G \in \Gamma$, *and for a direct correlated equilibrium* $d \in C(G)\backslash CONV(G)$, *the disobedient strategy profile* d' *in the extended game* G_d *is the profile in which each player always chooses the action that is not recommended by the mediator. For a 2x2 game* $G \in \Gamma$, *a direct correlated equilibrium* $d \in C(G)\backslash CONV(G)$, *is said to suffer from the multiple equilibrium problem if the correlated distribution, induced by the disobedient strategy profile,* $d' \in \{I(d) \cap CONV(G)\}$, *and* $\Sigma_{s \in S} d'(s)\mu_i(s) \geq \Sigma_{s \in S} d(s)\mu_i(s)$ *for all* i, *with at least one strict inequality.*

Definition 7 *Suppose for a given 2x2 game* $G \in \Gamma$, *a non-canonical correlation device induces a direct correlated equilibrium that suffers from the multiple equilibrium problem. We would say that the non-canonical device itself does (does not) suffer from the multiple equilibrium problem as well, if the strategy profile that corresponds*[9] *to the disobedient equilibrium of the direct extended game is (is not) an equilibrium in the non-canonical extended game.*

3 Multiplicity of Equilibrium

This section studies a general version of the two-person game of Chicken as the basic game. Motivated by the example in the Introduction, it considers a particular direct correlation device which is characterised by a single parameter, p.

3.1 The Game

Consider the two-player non-coöperative game of Chicken as in Figure 2*a*, where[10], $0 < a < b < c < d$. Each of the two players has two strategies, namely, A and P. This game has two pure Nash equilibrium, namely, (A, P) and (P, A) and a mixed equilibrium in which each player plays A with probability $(d - c)/\{(d - c) + (b - a)\}$.

	A	P
A	a, a	d, b
P	b, d	c, c

Figure 2*a*

3.2 The Canonical Correlation Device

Motivated by the examples in the Introduction, we here present a particular form of a direct correlation device as in Figure 2*b*. The device is characterised by one parameter, p, $0 < p < 1$.

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[9] There always exists such a strategy profile and can be easily identified by combining two maps.

[10] We have chosen strictly positive payoffs just for the sake of simplicity in calculations.

$$\begin{array}{ccc} & A & P \\ A & p & \frac{1-p}{2} \\ P & \frac{1-p}{2} & 0 \end{array}$$

Figure 2*b*

Fix a game of Chicken (i.e., fix values of a; b; c and d in the game in Figure 2a). Suppose now this game is played using a correlation device as in Figure 2b. Clearly for certain values of the parameter p, both the obedient and the disobedient strategy profile will be equilibrium of the canonical extended game. Note that, by the structure of the device and the payoffs in the original game (Chicken), the disobedient strategy generates higher payoffs than the obedient one, for both players. Thus, for a fixed game of Chicken, one can find a precise range of the parameter *p*, for which this correlated equilibrium suffers from the multiple equilibrium problem.

Proposition 1 *The (direct) correlation device in Figure 2b is a correlated equilibrium and also suffers from the multiple equilibrium problem if* $0 < p \leq Min[x,y]$*, where,* $x = (d - c)/\{(d - c) + 2(b - a)\}$ *and* $y = (b - a)/\{(b - a) + 2(d-c)\}$.

Proof. Assuming that the other player is following the strategy *AP* , it is obvious (by the symmetric structure of the device and the payoffs of the original game) that a player will play *P* when the recommendation is *P* and when the recommendation is *A*, will play *A* if $ap + d(1 - p)/2 \geq bp + c(1 - p)/2$, i.e., if $p \leq x$. Thus, the obedient profile (*AP, AP*) is a Nash equilibrium of the canonical extended game if $p \leq x$. Similar argument shows that the disobedient profile (*PA, PA*) is a Nash equilibrium if $p \leq y$.

To understand the above Proposition, let us consider the following example already discussed earlier.

Consider the game in Figure 1*a*. Here, $a = 0$, $b = 2$, $c = 6$ and $d = 7$. For these parameter values, $x = 1/5$ and $y = 1/2$. Therefore, any direct device as in Figure 2b will suffer from the multiple equilibrium problem if $0 < p \leq 1/5$. As noticed earlier, for this game, the device in Figure 1b, which is characterised by $p = 1/5$, does suffer from the multiple equilibrium problem.

For the rest of the paper, let us hereby fix a game of Chicken (i.e., fix values of a; b; c and d). Also, let us restrict ourselves to direct devices as in Figure 2b, with $p \leq Min[x, y]$ only, so that the correlated equilibrium in question does suffer from the multiple equilibrium problem.

4A Non-canonical Device

Consider the non-canonical device[11] in Figure 3*a*, in which the message sets for two players are, respectively, $\{a, b, c\}$ and $\{d, e, f\}$.

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[11] First appeared in Ray (1996b).

$$\begin{array}{cccc} & d & e & f \\ a & 0 & 0 & \frac{1}{7} \\ b & \frac{1}{7} & \frac{3}{7} & 0 \\ c & \frac{2}{7} & 0 & 0 \end{array}$$

Figure 3*a*

Suppose this device is used to play a version of Chicken, as in Figure 3*b*.

$$\begin{array}{ccc} & A & P \\ A & \frac{4}{3}, \frac{4}{3} & 7, 2 \\ P & 2, 7 & 5, 5 \end{array}$$

Figure 3*b*

Each player first gets a private message from the non-canonical device, and then plays the game. A pure strategy of a player in the extended game is a map from the set of messages to the set of pure strategies of the original game.

It is easy to check that the strategy profile (*P AP*, *A PA*) is a Nash equilibrium in this non-canonical extended game. This equilibrium strategy profile induces a probability distribution over the outcomes of the original game, as illustrated in Figure 3*c*.

$$\begin{array}{ccc} & A & P \\ A & \frac{1}{7} & \frac{3}{7} \\ P & \frac{3}{7} & 0 \end{array}$$

Figure 3*c*

The distribution in Figure 3*c* can now be identified as a direct correlation device. It is well known as the revelation principle (Myerson (1982), (1985)) that this induced (direct) device is also a (direct) correlated equilibrium for the game in Figure 3*b*. However, note that, this correlated equilibrium suffers from the multiple equilibrium problem. as indeed, the disobedient strategy profile (*PA*, *PA*) is also a Nash equilibrium of the (canonical) extended game and it generates higher payoffs than the obedient equilibrium. To use the result depicted in the Proposition, note here $a = 4/3$, $b = 2$, $c = 5$, $d = 7$, $x = 3/5$ and $y = 1/7$. Hence any direct device as in Figure 2*b* will suffer from the multiple equilibrium problem if $0 < p \leq 1/7$. The device in Figure 3*c*, which is characterised by $p = 1/7$, does suffer from the multiple equilibrium problem.

It is more important to note that the non-canonical device in Figure 3*a* (that induces the canonical distribution in Figure 3*c*), does not suffer from this problem, as the strategy profile (*AP A*, *PAP*); that corresponds to the disobedient profile in the canonical game is not an equilibrium in the non-canonical extended game.

The above example shows that it is possible to generate the obedient equilibrium and at the same time avoid the multiple equilibrium problem if one considers a non-canonical device such as the one in Figure 3*a*. One now might be interested in the structure of such non-canonical devices that would get rid of the multiple equilibrium problem. The device in Figure 3*a* does have a special structure. It is evident that the message profile (a, f) in this device is a public message or a sunspot. Introducing a public message or a sunspot in the non-canonical device is however not the only way to do this job, as the following example shows.

Consider for example, the game in Figure 3*b* and the correlated equilibrium in Figure 3*c*. One can induce the correlated equilibrium using the non-canonical device in Figure 3*d* that involves no sunspot. It is easy to verify that in this noncanonical extended game, the strategy profile (*AAP*, *AAP*) is an equilibrium and it induces the direct correlated equilibrium in Figure 3*c*. However, the strategy profile (*P PA*, *PP A*) that corresponds to the disobedient equilibrium in the canonical game is not an equilibrium of this non-canonical extended game.

$$\begin{array}{cccc} & d & e & f \\ a & 0 & \frac{1}{14} & \frac{3}{14} \\ b & \frac{1}{14} & 0 & \frac{3}{14} \\ c & \frac{2}{7} & \frac{1}{7} & 0 \end{array}$$

Figure 3d

It is important to realise that the above non-canonical structures (as in Figures 3a and 3*d*) may not work to get rid of the multiple equilibrium problem for all such games. For example, it can be shown that for the game in Figure 1*a* and the correlated equilibrium in Figure 1*b*, one cannot find any non-canonical device, structurally similar to that in Figure 3*a* or Figure 3*d*, that does not suffer from the multiple equilibrium problem.

5 Conclusion

This paper studies the multiple equilibrium problem in normal form games played using correlation devices and asks the question whether there exists a communication scheme, more specifically, a non-canonical correlation device that can implement a correlated equilibrium and does not suffer from the multiple equilibrium problem. An early example does suggest that it is indeed the case. The question that then arises is what kind of non-canonical devices one needs to achieve this. One possible way is to include a sunspot in the noncanonical device, as an example indicates.

The paper does not provide any general result. It only considers a 2*x*2 game

(Chicken) and a specific form of multiple equilibrium problem using a particular disobedient strategy. In this framework, sunspots in the non-canonical device turn out to be neither sufficient nor necessary to solve the problem. One definitely needs a different structure, possibly with larger message sets for each player, for these games.

For future research, one might consider a couple of different directions. First, as mentioned earlier, it is now well known that mediated and unmediated (cheap) talk can generate any correlated equilibrium of a given game. Particularly, any correlated equilibrium can be generated by a (one-shot public) mediated talk (Lehrer (1996), Lehrer and Sorin (1997)) or pre-play unmediated communication (Ben-Porath (1998)). Both these schemes are valid for 2*x*2 games. It would therefore be interesting to analyse the games and the correlated equilibrium distributions discussed in this paper in their framework. Second, one reckons that the non-canonical structure discussed here might be useful to model and analyse communication between (two) agents in any group decision problem in the bounded rationality literature (Chapter 6, Rubinstein (1998)).

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